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Water Mist Sprinkler Requirements for Shipboard Fire Protection

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16. Abstract

The current status of water mist (water fog and water mist are used interchangeably throughout this report) fire suppression system technology applicable to shipboard accommodation spaces and service spaces is reviewed. The review includes phenomenological descriptions, both old and new system designs and applications, and results of previously reported fire tests. Comparisons with conventional automatic sprinkler systems show that the special attributes and limitations of water mist systems warrant special system approval and installation guidelines.

A draft standard for approval of water mist fire suppression systems and components has been prepared by Underwriters Laboratories (UL) as part of this project. The draft standard parallels ISO 6182-1 for automatic sprinklers, but includes additional fire tests, and tests for essential and unique mist system components, such as strainers in the water delivery piping. A summary of the fire tests in the draft standard are presented along with a discussion of the need for additional testing and installation guidelines.

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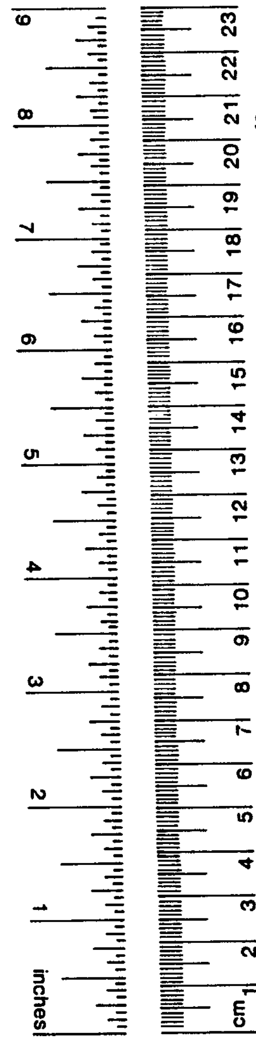
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

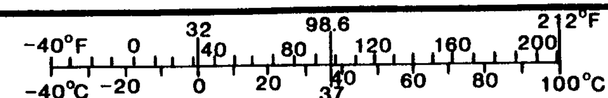
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

Water mist sprinkler systems differ from conventional sprinkler systems in that they produce a characteristic drop size at least one order-of-magnitude smaller than the roughly 1 mm drops of standard 1/2-inch (1.3 cm) orifice sprinklers. The smaller drops absorb heat more efficiently and rapidly. This means fire suppression can often be achieved with only a small fraction of the water demand of conventional sprinklers. Relatively low water demands are also due to the smaller fire size at the time of water discharge, since most water mist systems are activated by smoke or other special detectors. The low water demands are particularly attractive for shipboard applications, where large and prolonged water discharge rates can cause weight and stability problems. The smaller piping and nozzles associated with water mist systems are also desirable for possible retrofit installations.

Water mist sprinkler systems are now commercially available for installation in both passenger vessels and merchant ships. As of March 1993, one manufacturer had installed fog systems in nine European vessels and was in the process of installing seven more (Turner, 1993). European shipping authorities approved the systems after reviewing results of fire tests demonstrating system effectiveness. These tests are summarized in Section 2.5 of this report.

The advent of this new fire protection technology has raised several questions regarding potential U.S. Coast Guard and International Maritime Organization (IMO) approval and regulations. To what extent are the existing sprinkler approval requirements (ISO 6182-1.2) applicable and appropriate for water mist systems? How should the existing installation regulations (Regulation II-2/12 of SOLAS 74) be modified to accommodate water mist systems? Indeed, is it appropriate to treat mist systems as a special type of sprinkler system, or do they warrant entirely separate applications, regulations and guidelines?

This report addresses the preceding questions primarily for water mist systems intended to provide protection for shipboard accommodation spaces (lounges, dining rooms, corridors, cabins, etc.) and service spaces (galleys, laundry rooms, baggage rooms, etc.). The current status of relevant water mist sprinkler technology is summarized in Section 2. Details of fire tests conducted with mist systems in simulated cabins and lounges are provided in Appendix A. A draft standard for testing water mist system components is presented under separate cover as Appendix B. The rationale behind the draft standard, a review of the fire tests in the standard, and a comparison with ISO 6182-1.2 are described in Section 3. Additional work needed to develop effective installation criteria is discussed in Section 4.

2.0 WATER MIST SPRINKLER TECHNOLOGY

2.1 Mist Suppression and Transport Phenomenology

Flame cooling is generally considered to be the primary water mist suppression mechanism for flaming fires in a relatively large area. The basic concept is that extinction occurs when the flame temperature is reduced to the point that there is insufficient heat feedback from the flame to sustain the vaporization or pyrolysis of a liquid or solid fuel. The theoretical minimum concentration of water mist required for extinction depends on the assumed critical flame temperature for extinction. This temperature depends somewhat on the fuel and type of combustion. Carhart et al., (1992) assumed a critical flame temperature of 1600°K and calculated a required water mist concentration of 20 g/m^3 of flame (or enclosure) volume. Ewing et al., (1984) used a critical flame temperature of 2165°K and calculated a required water mist concentration of 39 g/m^3 for a hexane diffusion flame, in good agreement with laboratory test data.

In the case of a fire in a relatively small enclosed area, water vapor accumulation (from vaporized mist) and dilution of ambient air can be another important suppression mechanism. The required water vapor concentration and/or time of suppression can be estimated in terms of the concentration or time needed to reduce the oxygen concentration to roughly 12 percent by volume (v%) for most fuels. For a given enclosure volume and ventilation rate, the oxygen concentration at water mist activation will decrease with increasing fire size. This was illustrated in some water mist experiments (Mawhinney, 1993) in which a 2 MW fire was more rapidly suppressed than a 600 kW fire, because the oxygen concentration at mist activation was only 15 v% for the 2 MW fire.

In the case of a smoldering fire or deep-seated fire, and in situations where the mist cannot reach or penetrate the flame, the water mist needs to cool the solid combustible in order to achieve and sustain extinguishment. In these situations, the relevant mist parameter is the water flux (flow rate per unit combustible surface area) rather than the suspended mist concentration. Friedman (1992) has reviewed some sample laboratory test data for fine water sprays applied to flaming surface combustion of various plastics and woods. In the absence of an external heat flux from an exposure fire, only 1.5 to 3 grams per second per $meter^2$ is required for suppression. Additional water is needed for the deep-seated fires and for fires burning under the influence of an external heat flux.

The major difficulty in trying to utilize the preceding mist suppression data is the need to account for water mist inefficiencies: incomplete vaporization in the flame or on the burning surface, and drops that never reach either the flame or the burning combustible. The latter is due to water evaporation away from the fire, from water mist entrainment into the fire plume, and to water wetting of enclosure walls and obstructions. Mawhinney has conducted some experiments to quantify the effect of obstructions in the form of simulated piping grids in the path of the water spray. Spray fluxes were reduced by as much as 57% in passing through the piping obstructions.

Water mist transport losses are particularly important in large enclosures and other applications in which the mist nozzles are located far from the fire site. Smaller drops have less momentum than large drops (unless the mist droplet velocity is increased substantially compared to the large drop velocity), and gravitational forces are not as effective in delivering the mist to the burning fuel below. The inability of the mist droplets to penetrate the fire plume and ceiling layer suggest that a more effective delivery path would be from the side or under the flame. Turner (1993) has reported on attempts to utilize this approach by installing fog nozzles in recesses in the floor of a ship engine room.

2.2 Mist Nozzle Designs

The three generic nozzle designs for producing a water mist are moderate pressure nozzles, high pressure nozzles, and air atomizing nozzles. All three designs have been used to generate water sprays with a volume mean drop size of approximately 100 micrometers ($\pm$ 40 μm) or less. However, there are important differences in the spray velocities, flow rates, and reliability, as well as important differences in equipment and pressure requirements among the different designs as described below.

Moderate pressure nozzles operate at pressures of the same order-of-magnitude as those in conventional sprinkler systems, i.e., 200 to 700 kPa (30 to 100 psig). The relatively small orifice size corresponds to a typical K factor (flow rate divided by square root of pressure) of 1.3 lpm/kPa$^{1/2}$ (0.9 gpm/psi$^{1/2}$), which is about 17% as large as a standard 1/2-inch (1.3 cm) orifice sprinkler. According to Mawhinney (1993), the main disadvantage of the moderate pressure mist nozzles is that the total water flow rate requirement for suppression is relatively high compared to the other mist nozzles designs, because the moderate pressure nozzles produce larger drops (drop diameter varies inversely as the one-third power of pressure for a given size orifice) and larger flow rates per nozzle.

High pressure nozzles operate at pressures much higher than those used for conventional sprinklers. For example, the Ultra-Fog system operates at a working pressure of about 180 bar (18 MPa, 2610 psi) upon system activation. Some designs, such as the Marioff Hi-Fog, utilize clustered nozzles on a single sprinkler head. Presumably, the clustering produces a larger "throw distance" (from a higher momentum spray) and a broader spray envelope. Other designs are impingement nozzles which direct the water jet emerging from the orifice against either a small deflector (such as a cylindrical pin or spiral centerpiece) or head, or against an identical stream to produce the desired spray without resorting to such high water pressures. However, the impingement reaction usually reduces the spray momentum and projection compared to the other types of nozzles. Since the high pressure nozzles have the smallest orifices of the various mist nozzle designs, they could be more prone to plugging with pipe debris, unless special precautions such as filters and stainless steel pipes are incorporated into the system design.

Air atomizing nozzles generate a mist by injecting compressed air (or nitrogen) into or around the water jet. A typical design tested by Mawhinney (1993) utilized a nozzle water pressure of 410 kPa (60 psig) and an air pressure of 550 kPa (80 psig). The major advantage of the air atomizing nozzles is the ability to generate a fine drop size distribution without resorting to either small orifices, high pressures, or external deflectors that decrease spray momentum. They are less prone to plugging or damage from water-borne debris, but they do entail a considerable increase in equipment and complexity, because of the compressed air generation and distribution requirements. Furthermore, by injecting air into the fire enclosure, they would be less likely to achieve suppression by oxygen dilution/vitiation in small enclosures. Of course, this limitation can be removed and turned into an asset, if the compressed air injection was replaced by nitrogen injection.

2.3 Old Mist System Designs and Applications

Old mist systems are defined here as systems developed and installed in the forty year period between 1940 and 1980. Information on these systems and applications was gleaned primarily from conversations with a few fire protection engineers, such as Mr. Jack Rhodes, who were professionally active for a large span of that period.

The major impetus for developing the older water mist suppression systems was the need to fight flammable liquid fires before the advent and widespread production of fire fighting aqueous foam and foam proportioning systems. This was particularly important for shipboard fire fighting during World War II and its aftermath.

Most of the older water mist systems were manual, with fog nozzles mounted at the end of hose lines. This limited the types of nozzles to moderate pressure types frequently using impingement nozzle designs. The nozzles were effective, providing they did not clog and the fire fighters could approach the fire to within the nozzle "throw distance." In order to prevent clogging and plugging, expensive Monel strainers were used.

During the latter part of this period, automatic high-speed actuation systems were introduced for weapons magazines, and for propellant manufacturing plants. The authors were not able to get documented or personal descriptions of operating experience with these weapons magazine systems, but apparently many such systems are still in operation.

There does not seem to be any accounts of the older systems being installed in either shipboard or land applications tantamount to accommodation or service spaces. In other words, the older water fog systems were used for special applications rather than as substitutes for conventional sprinkler system applications.

2.4 New Water Mist System Designs and Applications

There are a wide variety of new designs for water mist fire suppression systems. Figure 2-1 shows a simple design in which the high pressure water supply comes from a nitrogen pressurized cylinder, and the system is actuated from a control panel wired to detectors located adjacent to each of the mist nozzles. As in a deluge sprinkler system, all the nozzles in this simple design would begin flowing upon activation.

The more sophisticated systems may have actuation elements (both thermal and electrical) on the nozzles or nozzle clusters, may have both pumps for moderate pressure operation and high-pressure accumulators, and may have elaborate valving and control subsystems. A general block diagram of the various subsystems and components is shown in Figure 2-2. Every system would have a control subsystem, water supply subsystem, water delivery subsystem, and alarms. Some systems also have separate detection and compressed air subsystems.

Besides shipboard accommodation and service spaces, some of the new water mist system applications include ship engine rooms, machinery spaces, and control areas. Other applications currently under study or installation include aircraft cabins, tunnels and trains such as the Channel Tunnel system, oil and gas platform production modules, gas compressor stations, telecommunications facilities such as switching stations, computer rooms, and turbine-generators. Many of these applications are described briefly in various articles in Water Mist Fire Suppression Workshop, March 1-2, 1993: Proceedings (NIST, 1993).

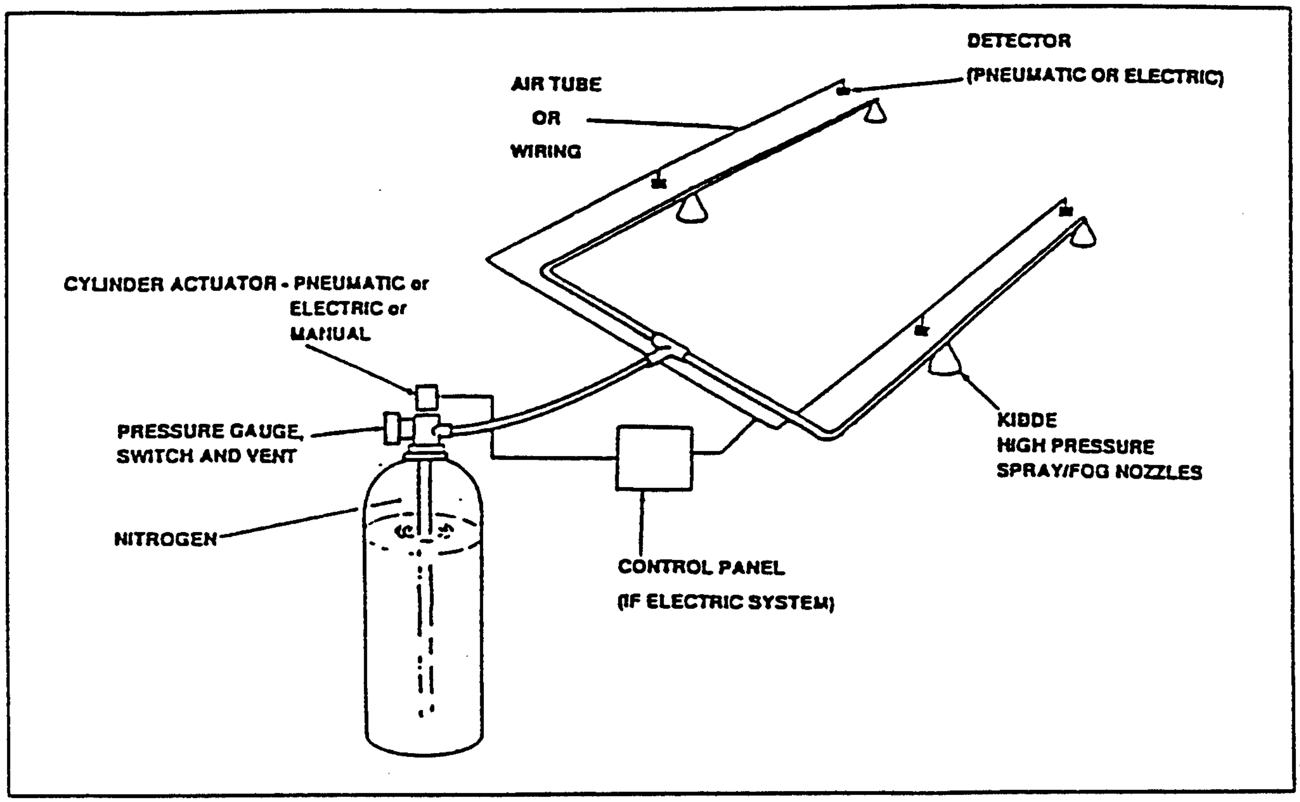

Figure 2-1. Simple System Design

(from Kidde-Graviner Water Spray/Fog Fire Suppression Data Sheet)

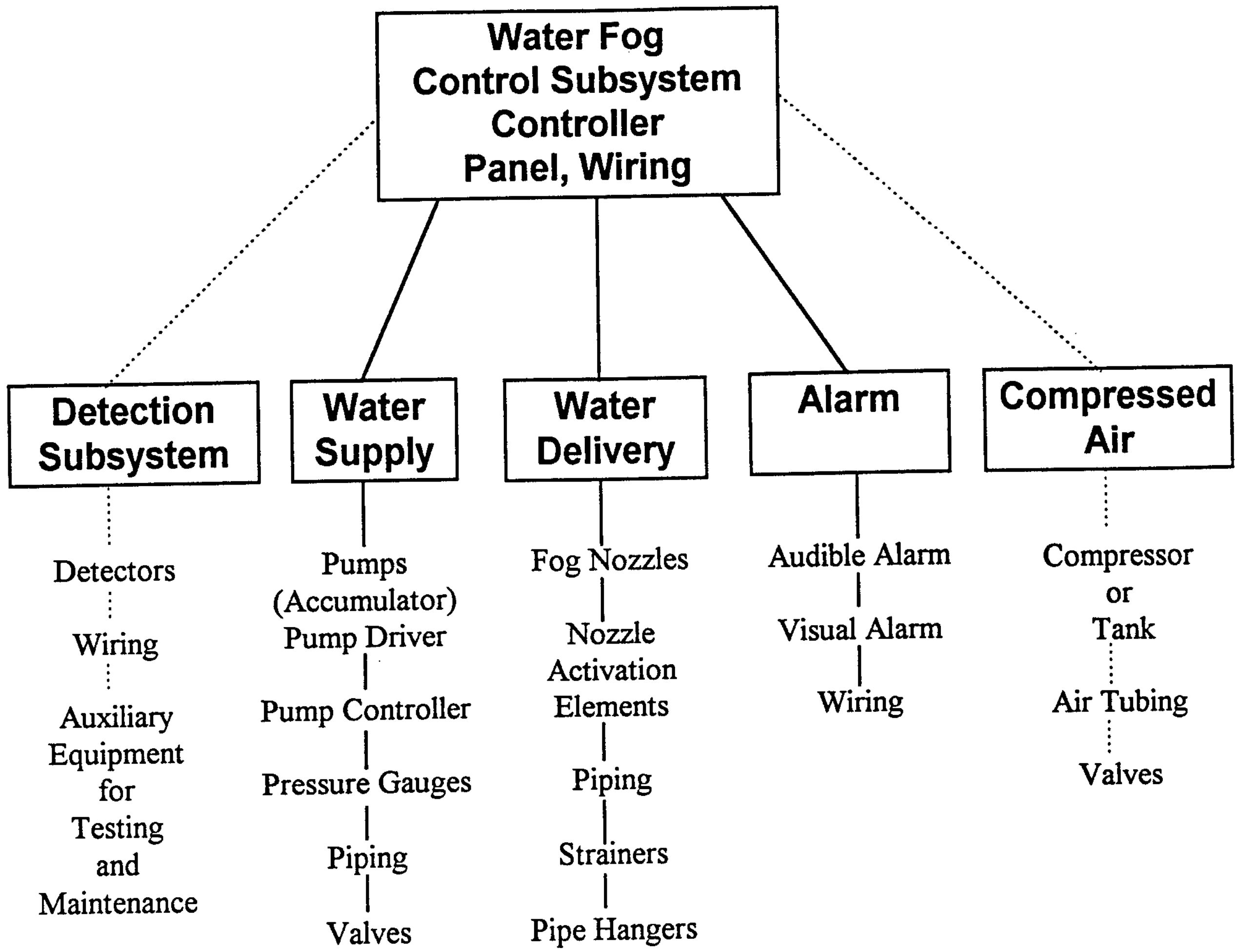

Figure 2-2. Fog Subsystems and Components

2.5 Fire Tests Relevant to Shipboard Applications

Several hundred large-scale water-mist fire suppression tests have been conducted with configurations simulating various shipboard applications. Relevant tests for this report pertain primarily to cabins and lounge/dining room configurations. The authors of this report have been privy to only a small subset of the test data; in particular, the data reported by Turner (1993) and by Arvidson and Ryderman (1992). A detailed review of this data is presented in Appendix A. A summary is given below.

The cabin tests were conducted in a 12 m^2 floor area, 2.4 m high test enclosure (apparently uninsulated) at SP, the Swedish National Testing & Research Institute. A single mist nozzle was installed on the cabin ceiling and responded to a mattress fire. In some tests, the mattress fire was shielded by an upper bunk bed. In some tests the cabin door was closed, while in other tests the door was opened allowing smoke to propagate into the adjacent corridor. The unshielded mattress fire developed more rapidly, but the shielded (top bunk down) mattress fire presented the greatest challenge (as measured by ceiling level gas temperatures) after nozzle activation.) The door open configuration presented a greater challenge than the door closed position.

According to Arvidson and Ryderman (1992), the Hi-fog water mist nozzles, with water flowing at 3.0 - 4.5 l/min, "gives equivalent or better reduction in the cabin fire compared with conventional sprinklers" operating at much higher (60 - 160 l/min) flow rates. These results are based on cabin temperature and fire heat release rate measurements. There were no measurements of carbon monoxide and oxygen concentrations, two other important parameters for lifesafety evaluations. Comparison of the results of various water mist tests, indicated that water mist effectiveness is enhanced significantly by early actuation (as with a smoke detector), and higher flow rates (e.g., 4.5 l/min).

The public space tests involved sofa fires and wood crib fires in various configurations and with various ceiling heights representing single deck (2.5 m high) and double deck (5 m high) applications. Multiple nozzles/heads (anywhere from two heads to eight heads) were activated with unspecified flow rates in these tests. It was very clear from the public space test results that the larger the space and the higher the ceiling, the less likely the mist nozzles are to achieve fire control (limiting the fire to the first item ignited) or suppression. Furthermore, delayed actuation of the nozzles renders fire suppression/control much more difficult even in the single deck (2.5 m high) tests. Apparently there were no direct comparisons with conventional sprinklers in the public space fire tests. However, the reports contain the subjective conclusion that effectiveness would have been comparable to conventional sprinklers providing the water mist nozzles are actuated as a group in the appropriate locations above and surrounding the fire. Both the Ultra-Fog system manufacturer and the independent test director (Arvidson, March 1993) state that it is "essential that the fog nozzles operate as deluge systems." The Ultra-Fog system manufacturer recommends that all the nozzles in the room (even in large rooms) be activated and that activation in rooms with double deck heights be based on signals from two smoke detectors (or optical detectors) as in cross-zoned deluge and total flooding gaseous systems. This point is discussed in Section 4, from the perspective of shipboard installation guidelines, and with the understanding that not all water mist systems employ deluge system activation.

Although the scope of this study does not formally include machinery spaces, several of the European shipboard water mist system installations (Turner, 1993) do include engine rooms.

Tests at SP and at the VTT Fire Technology Laboratory in Finland have simulated ship engine room fires. Both hydrocarbon spray fires and pool fires with heat release rates up to about 20 MW were used with an engine mock-up. Water mist nozzles were situated above, around, and, in some cases, under the engine mock-up. Results indicate that the ability of a water mist system to extinguish these high-challenge fires depends to a great extent on nozzle location and orientation (upward as well as downward sprays were used in some tests), as well as water flow rate and drop size.

2.6 Comparison of Automatic Sprinkers and Mist Systems

In small rooms such as cabins, water mist systems can act like automatic sprinklers with the closest comparison being to residential sprinkler systems. The response time of the mist system, in this application, can be comparable or faster than residential sprinklers, depending on whether the mist system is activated by a fast response passive thermal element, by an electrically energized element, or a smoke detector. The Appendix A comparison of cabin fire tests and residential sprinkler fire tests suggests that the rate of fire growth was greater in the residential sprinkler fire tests ($\alpha = 0.40$ kW/s^2) than in the cabin fire tests ($\alpha = 0.08$ kW/s^2). However, the shielded mattress fire used in the cabin fire tests would have presented a challenge to the residential sprinklers in that the sprinkler spray would be at least partially shielded from the fire. In fact, it is clear that the mist systems have an inherent advantage over conventional sprinklers for these shielded fires in a small cabin, providing suitable certification and system installation standards are developed. The development of such standards are discussed in Sections 3 and 4 of this report.

In large open rooms many water mist systems act more like deluge sprinkler systems (or total flooding gaseous agent systems) than closed head sprinkler systems. Performance in response to a given fire can be either far inferior, comparable to, or superior to conventional sprinklers depending on the ceiling height, room area, nozzle actuation time, nozzle spacing, and total water flow rates. These mist system parameters not only vary singificantly from one manufacturer to another, but also for one manufacturer's generic system design. The net result is that it would be a mistake to allow total substitution of mist systems for conventional sprinkler systems in these applications.

3.0 RATIONALE FOR DRAFT STANDARD ON WATER MIST SUPPRESSION SYSTEMS

3.1 General Approach

Appendix B of this report is a draft standard for water mist sprinkler system components, including pass/fail criteria, intended for shipboard use. The standard is intended to provide confidence that systems meeting its requirements have a fire suppression capability (for both performance and reliability) that is equivalent to equipment and systems that pass ISO 6182-1 for automatic sprinkler systems. This standard was prepared by Underwriters Laboratories (UL) in consultation with members of the IMO task group on water mist systems.

This task has been approached by using the tests and specifications of ISO 6182-1 wherever applicable, and by substituting more appliable tests to measure the performance and reliability factors that are either unique to water mist systems, or provide an unfair advantage for water mist systems. For example, ISO 6182 includes a wood crib fire test with a heptane spray fire serving to ignite the wood crib. Test results reported for at least one water mist system showed that the mist was capable of suppressing the heptane spray fire, as well as the developing crib fire if it was generated early enough and below a standard 2.4 m high ceiling. However, the small mist drops cannot penetrate a fire plume as readily as the larger water spray drops if they are released from a high ceiling. Therefore, the draft standard includes wood crib fire tests with the highest ceiling height specified by the system manufacturer for protection of ordinary hazard public spaces.

Another example of a more applicable measurement is the actual measurement of drop size distribution from the mist nozzle to verify that indeed a mist is being generated. This is not required for conventional sprinklers. The drop velocities will also be measured to provide an indirect measure of mist momentum or "throw distance."

The item-by-item differences between the draft standard and ISO 6182-1 are listed in Section 3.3. The various fire tests in the draft standard are discussed in Section 3.2.

3.2 Fire Tests in Draft Standard

Different fire tests are specified for water mist systems designed for machinery space areas, accommodation spaces, and public spaces. A brief summary of the test configurations is listed in Table 3-1.

Machinery space fire tests include oil spray fires for high risk areas (areas with pressurized liquids), and pool fires for both high risk and low risk areas. The oil spray fires consist of some tests with high flow rates and low pressures ($\leq$ 10 bar), and other tests with low flow rates and a nozzle pressure of 150 bar (2,175 psig). Room area and ceiling height depend on the size of machinery space installation. The water mist system in these tests is employed according to the manufacturer's specifications, with nozzle spacings and distances from the test apparatus determined by the maximum distances recommended by the manufacturer. The water mist system being tested is supposed to extinguish the machinery space fires within half of the manufacturer's specified discharge time or 15 minutes, whichever is less. One potential problem with these specifications is that the oxygen concentration is not measured, and yet UL allows for a test area and volume smaller than the typical Class 2 and Class 3 machinery spaces, provided the fire is not

Table 3-1. Fire Tests in Underwriters Laboratories (UL) Draft Standard

AREA	TYPE OF FIRE	FIRE SIZE	ROOM AREA (m^2)	CEILING HEIGHT (m)
MACHINERY SPACE				
Class 1 (Small)	Oil Spray: Low Pressure High Pressure Tray Pool Fire:	 0.16 kg/s @ 8 bar 0.05 kg/s @ 150 bar 2 m^2	80	5
Class 2 (Medium)	Oil Spray: Low Pressure High Pressure Tray Pool Fire:	 0.25 kg/s @ 10 bar 0.05 kg/s @ 150 bar 2 m^2	300 (1)	5-10
Class 3 (Large)	Oil Spray: Low Pressure High Pressure Tray Pool Fire:	 0.25 kg/s @ 10 bar 0.05 kg/s @ 150 bar 2 m^2	300 (1)	> 10
ACCOMMODATION SPACE				
≤ 12 m^2	Two Bunk Beds	1.6 m^2 mattress	12	2.4
> 12 m^2	Wood Crib + Simulated Furniture	0.3 m cube: 6 kg 0.9 m^2 cushion	24 (2)	2.4
PUBLIC SPACE				
Light Hazard	Four Sofas	1.6 m^2 mattress	≥ 80	≥ 2.5
Ordinary Hazard	Wood Crib	2.4 x.1.2 x 1.2 m	≥ 144	≥ 5

1. UL allows smaller area for spray fire tests, if fire is not oxygen vitiated.
2. The bunk bed fire test in the 12 m^2 room is also to be conducted for these areas.

affected by oxygen depletion. This will be very difficult to verify for the 10 MW (0.25 kg/s) oil spray fires, particularly since the water mist can generate copious quantities of water vapor upon injection into the flame or fire plume. Another potential problem is that the water mist nozzle orientation is not specified, and water mist effectiveness does depend on its discharge orientation relative to the spray fire.

The accommodation space fire test specified for small ($\leq 12\ m^2$) spaces is similar to the cabin tests previously conducted (Appendix A), except that wall insulation is used to retain more heat within the test enclosure. The fire test for large accommodation spaces is similar to the fire test used for residential sprinklers. Water mist nozzles in both accommodation space fire tests are installed and operated according to the manufacturer's specifications.

Public space fire tests depend upon whether the installation space is a light hazard area (defined qualitatively in terms of combustibility of materials) or an ordinary hazard area. The light hazard area fire test is similar to the public area tests previously conducted (Appendix A), while the ordinary hazard area test is similar to the ISO 6182 test for conventional sprinklers, except for the ceiling height specification mentioned in Section 3.1.

The fire tests listed in Table 3-1 should go a long way toward verifying the effectiveness of water mist systems for most shipboard areas. However, there are some areas that may warrant separate tests. For example, service spaces include storerooms and baggage rooms containing large quantities and storage heights of combustibles, some of which might be prone to deep-seated fires. The authors are not aware of any water mist system tests being conducted in this type of high challenge application. A particular test configuration could be developed based on a brief (and possibly informal) survey of materials and storage configurations in these rooms.

Crew quarters also warrant additional tests because of their larger areas, more congested berthing arrangements, and larger number of personnel at risk in a given area. One other type of area that could be amenable to water mist protection, if suitable fire tests were developed, is a control area containing critical electrical equipment, as in a control room or telecommunications center. Tests for this type of application would need to verify the compatibility of the mist discharge over energized electrical equipment.

3.3 Comparison of Draft Standard and ISO 6182-1

In addition to the item-by-item differences between the draft standard and ISO 6182-1, this section also indicates those sections of the draft standard which have no equivalent or are not included in ISO 6182-1.

ISO 6182-1 Section	Item	Comments
5.	Product Assembly	Not inlcuded in draft since the draft focuses on performance tests
6.1.	Dimensions	Draft allows for smaller orifices and threads; smaller orifices are allowed because of the use of strainers, as required; strainers have separate requirements in the draft
5.	Product Assembly	Not inlcuded in draft since the draft focuses on performance tests
6.2.	Release Temperatures	Same as draft
6.3.	Operating Temperatures	Same as draft
6.4.	Flow Constant K	Draft does not include dry sprinklers at this time
6.4.2.	Water Distribution	Draft requires tests for identification only, since set patterns do not apply to this device
6.5.	Function	Same
6.6.	Strength of Body	Same
6.7.	Strength of Release Element	Same
6.8.	Leak Resistance	Test pressures based on rated pressure
6.9.	Heat Exposure	Same
6.10.	Thermal Shock	Same
6.11.	Corrosion	Same: salt spray test is described in general requirements
6.12.	Coatings	Same
6.13.	Water Hammer	Test pressures based on rated pressure
6.14.	Dynamic Heating	Same
6.15.	Resistance to Heat	Same

Continued from previous page

ISO 6182-1 Section	Item	Comments
6.16.	Resistance to Vibration	Same
6.17.	Resistance to Impact	Not conducted: instead see Shock Test in General Requirement Test Methods of draft (Section 6.0 of Appendix B)
6.18.	Fire Performance	See Section 3.2 above
6.19.	Lateral Discharge	Same
6.20.	30 Day Leakage	Test pressures based on rated pressure
6.21.	Vacuum	Same
5.	General Requirements	Includes requirements for all components used in the system, assumptions, and intentions
7.1.4.3.	Water Droplet Size	Droplet size distribution and velocity distribution conducted for identification of discharge characteristics
7.18.	Fire Tests	See Section 3.2 above
10-21.	Individual Component Requirements	Specific reference for testing various components including shup-off valves, trim valves, regulating valve check valves, strainers, pumps, motors, pump controllers, gauges, pressure vessels, alarms, and pressure switches
22.	System Manual	Contains requirements for items and information regarding the design, installation, operation, and maintenance of the system

4.0 FURTHER DEVELOPMENT OF SHIPBOARD INSTALLATION STANDARD

The discussion in Section 2 (particularly in Section 2.6), and the nature of the fire tests in the draft standard, demonstrates the need to provide specific installation guidelines for water mist systems, rather than allow their installation as a direct substitution for conventional automatic sprinklers. Even after a water mist system passes the draft standard tests described in Section 3 and Appendix B, special installation regulations will be needed for their application in service and accommodation areas. These installation guidelines should address the following items as a minimum:

1) One important installation question for large areas is how the nozzles should be zoned upon actuation. Some manufacturers and researchers recommend deploying every nozzle in the area. However, this may not necessarily be appropriate in very large areas, because it would decrease the water pressure and flow rate for nozzles nearest the fire, and the water mist could decrease visibility to the point of hindering evacuation from the area. Furthermore, some systems have individual actuators for each nozzle or each nozzle cluster. Therefore, it is difficult to arrive at a general answer to this question, without reviewing the fire test results and the various system designs.

2) Another important installation question is the methodology for hydraulic calculations. Conventional sprinkler system designs employ the Hazen-Williams equation (NFPA 13) as the basis for estimated pressure drops and flow rates in various pipe sections. However, the Hazen-Williams equation may not be as applicable to water mist piping systems because of the different Reynolds number regime, and the possible importance of flow transients in the open nozzle systems.

3) A related question for open nozzle systems is the maximum acceptable water delivery time to the hydraulically most remote nozzle. One way to arrive at an answer to this question is to delay water discharge in the fire tests used as the basis for listing/approval of the system, and allow up to that delay in an actual shipboard installation.

4) Several maintenance and inspection questions need to be examined. For example, how often should the piping be flushed and the strainers cleaned or changed to avoid system plugging? How often should the pumps/accumulators be tested? These questions are probably best addressed through discussions with systems manufacturers, insurers, and ship operators together with Coast Guard personnel.

5.0 CONCLUSIONS

A draft standard for approving water mist fire suppression systems for shipboard use has been developed based on a parallel to ISO 6182-1 for automatic sprinkler systems. The version of the draft standard included as Appendix B of this report includes various fire tests established during discussions at a recent IMO meeting. The standard also includes tests for water mist nozzles and other system components, such as strainers, which are both essential and unique in mist systems, as opposed to conventional sprinkler systems.

Depending on the installation, the type of fire, and the system design and operating parameters, water mist systems can provide either inferior, comparable, or superior fire suppression/control compared to conventional sprinkler systems. It is therefore inappropriate to utilize water mist systems with the existing installation and maintenance/inspection guidelines for automatic sprinklers. More appropriate guidelines can be written for some shipboard areas, such as cabins, public spaces, and machinery spaces, from previously conducted test results. Other areas, such as crew quarters, storerooms and baggage rooms, and areas containing electrical equipment, warrant additional testing to develop a database for determination of appropriate installation regulations.

Other system issues warranting further consideration in the development of system installation and maintenance guidelines include: nozzle zoning in large areas, hydraulic calculation procedures, maximum acceptable water delay time for open nozzle systems, and appropriate inspection and testing intervals.

6.0 REFERENCES

Arvidson, M. (Swedish National Testing and Research Institute), Seminar at Factory Mutual Research Corporation, March 1993.

Arvidson, M. and Ryderman, A., "Cabin and Public Space Fire Tests with Ultra-Fog Fire Protection System," The Swedish National Testing and Research Institute Test Report R30187, August 1992.

Carhart, H.W., Sheinson, R.S., Tatem, P.A., and Lugar, J.R., "Fire Suppression Research in the U.S. Navy," First International Conference on Fire Suppression Research Proceedings, p. 337, available from National Institute of Standards and Technology, May 1992.

Ewing, C.T., Hughes, J.T., and Carhart, H.W., "The Extinction of Hydrocarbon Flames Based on the Heat-absorption Process which Occur in them," Fire and Materials, vol. 8, pp. 148-156, 1984.

Friedman, R., "Theory of Fire Extinguishment," The NFPA Handbook, Section 1/Chapter 6, 17th Edition, 1992.

ISO 6182-1.2, "Fire Protection - Automatic Sprinkler Systems- Part 1: Requirements and Methods of Test for Sprinklers," International Standards Organization, 1992.

Mawhinney, J.R., "Engineering Criteria for Water Mist Fire Suppression Systems," Water Mist Fire Suppression Workshop, March 1-2, 1993: Proceedings, National Institute of Standards and Technology, NISTIR 5207, Gaithersburg, MD, June 1993.

Rhodes, J.R., retired Chief Operating Officer, Factory Mutual Research Corporation, personal communication, May 29, 1993.

Turner, A.R.F., "Water Mist in Marine Applications," Water Mist Fire Suppression Workshop, March 1-2, 1993: Proceedings, National Institute of Standards and Technology, NISTIR 5207, Gaithersburg, MD, June 1993.

Appendix A

Summary of Reported Water Mist Fire Tests for Shipboard Accommodation and Service Spaces

The following table lists selected Marioff Hi-Fog fire test conditions and results reported by Turner at the March 1993 Water Mist Fire Suppression Workshop.

Test	Room Size	Height	Ventilation	Fuel	Result
1. Cabin/corridor Test 1.9 & 1.30-1.34 (See Note 1, 2)	Cabin: ~3 m x 4 m Corridor: ~12 m long	>150 cm (the temp location)	40 l/sec. & Door open/close	bunk mattresses, in 2 sets of 2 pullman beds, one on top of the other.	Fire Hazard is reduced to that by conventional sprinklers or better with 1 Hi-Fog head.
(See Note 3)				Arsonist Fire w/ white spirits on bed mattress	
				Flashover fires 1 MW, manual sprinkler activate	
2. Large Room Test 2.21 & 2.22	9.6 m x 6.0 m	3.10 m	Unknown ventilation or door positions other than an open room	2 sofas-cold foam, fire started on one sofa	Control fire with 2 of 5 Hi-fog heads which activated automatically
3. Open Space	10 m x 10 m	2.5 m & 5 m	open room	restaurant arrangement ?	Control furniture group if 100 m^2 deluge system only

Notes:
1. Fuel of bunk beds as described in Ultra-Fog test; fuel in other tests are unknown.
2. One Hi-Fog Nozzle was located between the stacked bunk beds at 0.65 m from the wall at the head of the beds, the other sprinkler was located in the middle of the corridor width, just outside the cabin door. It was not reported which heads went off to control the fire.
3. No other details were given for the other tests.

The following Table lists typical test conditions and results for the Ultra-Fog Suppression System as reported by the Swedish National Testing and Research Institute in August 1992 (Arvidson, 1992).

Test	Room Size	Height	Ventilation	Fuel	Result
Cabin Corridor	3 m x 4 m 12 m long	2.4 m	1 Open/close door. 60 l/sec forced air in ceiling.	Lower bed	Prevents fire to flashover in cabin. Temp. in cabin & corridor to low levels.
Public open room	8 m x 10.2 m	4.8 m	Open room	(2) sofas & wood crib configurations	Extinguish small fires from spread to nearby object. Smoke layer temp. 100°C.

Cabin Description:

Sprinkler Description:

One Ultra-Fog nozzle in the cabin was activated by a smoke detector also located in the cabin; two other Ultra-Fog nozzles were located in the corridor 5 m apart activated by a another smoke detector in the corridor near the cabin door.

Bunk Bed Description:

Standard polyether mattresses in pullman type bunk bed; the lower beds had a backrest of same material as beds. Two types of mattress material: coldfoam & polyether and pillow of the same material as the mattress.

Fire Description:

Small woodcrib and 2-3 ml of heptane at the head end of lower bed; the lower bed backrest of same unknown material as the bed. The amount of burning material was sufficient for flashover (see test 1.34 HRR in Turner (1993)); bed fire damage was from visual observation.

In the **Ultra-Fog** Tests for the **cabin/corridor test** variations that are different from the above information:

Test No. in Report	Ventilation* 60 L/min & the following:	Sprinklers Active	Nozzle Flow l/min	Fuel Arrangement**	Results - Maximum Values			
					HRR kW	Cabin °C	Cabin Release °C	Corridor °C
1.1	Door Closed	Automatic Cabin (1) nozzle only	3.0	coldfoam mattress	----	120	50	----
1.5			3.0	coldroam mattress	----	110	40	----
1.2	Door Open	Automatic Cabin & Corridor (3) nozzles	3.0	coldfoam mattress	150	170	50	90
1.6			3.0	coldfoam mattress	120	170	70	120
1.7			3.0	polyether mattress	130	180	80	120
1.9			4.5	polyether mattress	80	200	50	80
1.10			4.5	polyether mattress	100	160	120	110
1.11	Door Open	Automatic Cabin & Corridor (3) nozzles	4.5	upper bed raised, polyether mattress	110	420	110	160
1.3	Door Open	Automatic Cabin & Corrodor (2) nozzles	3.0	coldfoam mattress	500	340	100	280
1.12	"	"	4.5	polyether mattress	850	780	540	470

Continued from previous page:

Test No. in Report	Ventilation* 60 L/min & the following:	Sprinklers Active	Nozzle Flow l/min	Fuel Arrangement**	Results - Maximum Values			
					HRR kW	Cabin °C	Cabin Release °C	Corridor °C
1.4	Door Open	Manual cabin & corridor (3) nozzles	3.0	Flashover prior to activation, coldfoam mattress	1590	790	120	490
1.8			3.0	Flashover prior to activation, polyether mattress	1670	720	70	570

* All had forced air of 60 L/sec located in the center of the ceiling of the room.

** The 4 pullman bunk beds are arranged in two stacks with two beds in one stack, unless noted otherwise.

Note:

1. The cabin release temperature is the maximum temperature in the cabin after 10 minutes after the release of the Ultra-Fog heads of water spray.
2. All temperatures and Heat Release Rates (HRR) are the maximum values and are rounded to the nearest tenth.

In reviewing the **Cabin/Corridor** Test Summary of the **Ultra-Fog** report (Arvidson, 1992) the following conclusions can be made for the **worst case** test scenario:

In all the situations below, where there are two tests of the same design, the data used for the comparison is not entirely conclusive for all the data categories. Thus, in making the best of the data presented, the following conclusions are drawn.

1) <u>Water Flow</u>--3.0 l/min. vs. 4.5 l/min.-- the lesser flow is the worst case, for the following:

there is only one test combination to compare where all the other parameters except the water flow is the same. In the second test scenario, comparing Tests 1.7 with Tests 1.9 & 1.10, the maximum heat release rate (HRR) is 30-50 kW higher for the lesser flow and the corridor maximum temperatures are 10-40°C higher for the lesser flow. Both the cabin maximum temperature and the temperature in the cabin 10 minutes after the water release are inconclusive,

2) <u>Door Position</u>--Open vs. Closed--Open door is worst case:

in comparing Tests 1.1 & 1.5 with Tests 1.2 & 1.6, there was no HRR measured with the door closed due to the closed door blocking the products of combustion from reaching the fire products collector at the end of the corridor. With the door open, the cabin maximum temperature was 50-60°C higher, and ten minutes after the water release the cabin temperature was 10-30°C higher. Thus the open door is the greater challenge,

3) <u>Mattress Material</u>--Coldfoam vs. Polyether--the polyether is the worst case:

a. in the second test scenario with the door open and all heads activated, comparing Tests 1.2 & 1.6 with 1.7, it is inconclusive which material is the worse hazard. What is obvious is the earlier the fire is detected and therefore extinguished, the less time the hazard has to get worse. Ten minutes after the sprinkler comes on, the polyether is at a higher temperature by 10-20°C, and the maximum cabin temperature for polyether is higher by 10°C,

b. in the fourth test scenario with the heads in the cabin deactivated for both materials and with a greater water flow from the corridor heads for the polyether than the coldfoam, comparing Tests 1.3 with 1.12 the polyether is the worst case. The polyether reached flashover and the coldfoam was just below flashover with the polyether maximum HRR 350 kW higher, polyether's cabin maximum temperature is 440°C higher, polyether's corridor maximum temperature is 190°C higher, and the cabin maximum temperature ten minutes after sprinkler activation for polyether is 440°C higher,

c. in the fifth test scenario, where both materials went to flashover, the maximum HRR was 80°C higher for the polyether, but the cabin maximum temperatures were slightly lower or equal for the polyether. The cabin temperature ten minutes after the spray released was much lower for the polyether, meaning the spray sprinklers did a better job of putting out the polyether than the coldfoam fires. However, the corridor temperatures were 80°C higher for the polyether. Both materials in the cabin were completely burned out,

4) **Top Bunk Position**--Up vs. Down--top bunk UP has the worst fire hazard levels, but the top bunk down had higher hazard levels (+10°C) after the extinguishment:

   a) with the top bunk in the Up position, the fire is in the lower bunk exposed to the water spray, with the top bunk in the Down position, the fire is in the lower bunk shielded from the water spray by the top bunk,

   b) in comparing the only two tests with all other parameters equal, Test 1.10 and Test 1.11, the top bunk in the up position is a higher challenge due to its HRR being higher, 10 kW (but not that much higher), and its cabin and corridor maximum temperatures being higher by 260°C and 50°C, respectively; however, ten minutes after the water released, the cabin temperature is lower by 10°C for the top bunk in the up position, meaning the spray better extinguished the higher challenge of the fire exposed to the spray (top bunk up), rather than the shielded fire with the top bunk down,

   c) the top bunk up developed worse fire conditions because of the unrestricted air flow to feed the fire growth, and this higher challenge fire was extinguished easier because the unshielded fire was exposed to the water spray directly. Allowing a larger fire in the shielded bunk case by less restrictive air flow or more time may provide this system with a more meaningful test situation. However, in the real application this latter case may not be applicable because of unreal air flow or because of the unreal time due to the fast response by the smoke detectors.

5) **The Test Report Conclusions** by the lab and manufacturer for the Cabin/Corridor Tests were:

   a) "When the door is closed the system keeps the maximum temperature in the cabin to levels around 100°C."

   b) "When the door is closed the HRR is kept between 80 and 150 kW."

   c) "The higher water flow rates [4.5 l/min.] had a significantly better effect than the lower flow [3.0 l/min.]."

   d) "When a malfunction [of the sprinkler head in the cabin occurred, (Tests 1.3 & 1.12 above)] most of the material in the cabin burned out and relatively high temperatures were measured just outside the corridor, however, the system prevented the fire in the cabin to reach flashover when cold foam mattresses were used."

e) "When activated at flashover the system reduced the temperatures in the cabin and the corridor, but all of the material in the cabin burned out."

Ultra-Fog tests for the **Public Space test** variations that are different from the first chart for Ultra-Fog:

Public Space Room Description

a) Sofa description:

Two sofas both made of coldfoam were arranged as:

- Perpendicular in middle of room
- Back to back in middle of room
- Perpendicular in corner
- Free Burn Test

Seating area in atrium space (not reported here because of different unknown room arrangement):

- White spirit spread over an arm of the chair and ignited

b) Fire Description:

- In one sofa, fire was started in a small woodcrib by a 2-3 ml heptane and the fire was observed to spread from this ignited sofa to the other sofa.
- All nozzles in the room (8) were activated 30 seconds after a smoke detector activated in the center of the ceiling; this time delay simulated the time for a second detector to activate prior to activating the Ultra-Fog sprinkler heads.

Public Space Test Scenario (Ultra-Fog)

Test No.	Fuel Arrangement	Max. Temp. °C 10 cm below ceiling	Damages to First Sofa		Damages to Second Sofa	
			Seat	Backrest	Seat	Backrest
2.1	Middle of Room, Sofas Perpendicular	60	95%	100%	None	None
2.8	Corner Test, Sofas Perpendicular	30	50%	80%	None	None
2.2	Middle of Room, Sofas Back to Back	20	Slightly	None	None	None
2.3	"	20	Slightly	None	None	None
2.4	"	20	50%	90%	Slightly	50%
2.7	"	50	90%	10%	Slightly	40%
2.11	Middle of room Sofas Back to Back, Free-Burn	160	100%	100%	100%	100%

Notes:

1. The gpm rating of Ultra-Fog Heads upon activation is unknown, but there are eight heads in the room with one smoke detector in the center of the ceiling to activate all 8 heads at once, the only exception to this set-up is the free-burn tests where no heads were allowed to activate
2. Not much is known about the atrium set-up in comparison to the Public Space set-up, therefore not considered in this analysis
3. The first sofa was the ignition one, and the second sofa ignited only if the fire spread from the first sofa. No other sofas were in the test.

In reviewing the **Ultra-Fog Public Space** Test Summary of the report the following worst case conclusions can be made:

a) Room Test Position--Middle of room is the worst case:

In comparing Tests 2.1 and 2.2, the only tests with similar set-ups, there was more damage to the first sofa though no fire spread in either case to the second sofa; the maximum ceiling temperature was also higher in the middle of the room case.

b) Furniture Orientation--Back to Back is the worst case:

Perpendicular: In Tests 2.1 & 2.8, the fire did not spread to the second sofa in this arrangement even though the first sofa was almost completely damaged, or

Back to Back: In Tests 2.2 & 2.3, the fire was extinguished in the first sofa seat due to "the small ignition source and the early (smoke detector) release of the system". However, in the Tests 2.4 & 2.7 that were not extinguished (unknown cause), the fire spread to the second sofa with significant damage to the first and second sofas.

The Test Report Conclusions besides the ones above:

- "It was noticed that the release of a group of Ultra-Fog, as in this case, almost immediately gives an atmosphere of smoke, vaporized water and fog with reduced visibility that could affect peoples possibility to escape. This is of course an effect that is seen with other water fog systems."
- "Although no comparison tests with traditional sprinkler were done it is felt that the results are, with exception of the previous comments [on smoke and limiting egress above] equal with traditional sprinklers. This is mainly an effect of the earlier release of the system compared to the traditional thermal activation devices."

  This claim cannot be confirmed because the HRR, the furniture size, etc. were not supplied in the report. However, an attempt will be made to compare the fog heads to that of the residential sprinklers in the next section for the cabin set-up only. The cabin's ceiling heights and room sizes are much smaller than this Public Space, thus the cabin's sprinkler comparison conclusions are not directly comparable to the Public Space. The ceiling temperature data could be adjusted by doing analytical analysis of the data with fire models. However, the fire models are not applicable after sprinkler actuation.

Comparison of Fog Mist Systems to Residential Sprinklers

The HRR curves from Hi-Fog Cabin/Corridor Test 1.34 (Turner 1993) are compared here to the HRR's in the Factory Mutual (FM) Residential Sprinkler Tests as reported in Bill (1988). The Hi-Fog test is the HRR with the sprinklers activating, and the Residential HRR is a free-burn up to the sprinkler activation, but it is known that the residential sprinkler will control this free-burning fire.

In this section the Ultra-fog and Hi-fog tests complement each other since what data is missing from one report is given in the other, i.e., the HRR is from Hi-Fog Test 1.34 (Turner 1993) and the room dimensions are from the Ultra-Fog Tests (Arvidson, 1992). The Hi-Fog and Ultra-Fog both have different room forced air ventilation rates (40 l/s for Hi-Fog; 60 l/s for Ultra-Fog), therefore, the Hi-Fog is the lower ventilation; thus a lower HRR is used in this analysis. This approach to use the Ultra-Fog dimensions with the Hi-Fog HRR is reasonable since the same testing lab did both tests. The receipt of the missing information will prove or disprove this analysis.

Using Figure 11 of Bill (1988) for the furniture combination used in the residential sprinkler tests up to sprinkler activation at about 130 seconds and the Test 1.34 RHR (referred to as HRR in this report) with the Hi-Fog nozzles actuating, the HRR parameters are shown in the following table. The Hi-Fog HRR is for the top bunk in the down position and the fire on the lower bunk shielded from the sprinkler. In comparing the two HRR curves:

	Residential Sprinklers	**Hi-Fog Nozzle**
Peak HRR from curves	896 kW	1050 kW
Time from 50 kW to HRR peak (less virtual time)	50 sec	120 sec
Time from 50 kW to 800 kW	45 sec	100 sec
Using NFPA 72 αt^2, $\alpha = 800/(\text{time from 50-800 kW})^2=$	0.395	0.080
Floor Area	3.6 m x 7.3 m (12' x 24')	3 m x 4 m
Ceiling Height	2.4 m (8')	2.4 m
Ventilation	Open Door & 2 windows (5'x1')	Open Door + 40 l/min

The α HRR growth rate parameter is roughly five times as large in the residential sprinkler test fire than in the cabin bunk fire. Thus the Residential furniture fire is a more severe fire growth.

The next question is: will the Residential sprinkler control the Hi-Fog bunk shielded fire, and can the Hi-Fog and Ultra-fog nozzles control this type of residential fire? There is no clear answer without the comparison tests, but some comments are offered on the relative challenges involved.

Will the sprinklers put out the Fog test? The shielded fire seems to be the question that cannot be answered here. Otherwise, from a HRR perspective, the answer is yes. In the Hi-Fog test with the top bunk up (unshielded fire), and less air restrictions to the fire, the Hi-Fog allowed a much worse room fire condition, which the residential sprinkler would have easily controlled due to an unshielded fire effect. In the above residential sprinkler fire the center ceiling temperatures over the ignition were limited to 121°C (Figure 17 Bill 1988) compared to 420°C in the cabin bunk up fire. With the shielded (top bunk down) fire, the Hi-Fog probably performed better than would a residential sprinkler (because the obstruction to sprinkler discharge is more pronounced with larger drops) although no data is presented here to confirm this.

Considering the size of the fire at sprinkler actuation, the residential fire had probably more mass involved in the fire than the thin mattresses but this is not a definite conclusion due to the lack of information on the Fog nozzle tests.

In comparison to wood crib fire tests used in listing conventional sprinklers (Bryan in Automatic Sprinklers and Standpipes, Figure 6.16 page 209), the peak HRR is 270 kW at sprinkler activation which is about one third the peak HRR of the furniture in Residential sprinkler tests, and the Cabin four bunk bed of the Hi-Fog Tests.

There is insufficient data given to perform this same comparison for the Public Space for both types of the Fog Mist nozzles (Hi-Fog & Ultra-Fog). However, it is felt that conventional sprinklers would put this fire out because of the unshielded fires, but with a larger water demand. This is assuming the conventional sprinklers would be activated early by a smoke detection system.

References

Bill, Kung, Brown, Hill, "Effects of Cathedral & Beamed Ceiling Construction on Residential Sprinkler Performance", FMRC J.I.OM3N5.RA, (Norwood, MA: FMRC) 1988.

Byran, John, Automatic Sprinkler and Standpipe Systems, 2nd ed., (Quincy, MA: NFPA) 1990.

Report No. 91 R30141, Turner, A., "Cabin and Public Spaces with Marioff's Hi-fog Fire Protection System" (Boras: Swedish National Testing and Research Institute) 1992.

Report No. 91 R30187, Arvidson, M. & Ryderman, A., "Cabin and Public Spaces with Ultra-Fog Fire Protection System" (SP) (Boras: Swedish National Testing & Research Institute) 1992.

Turner, A.R.F., "Water Mist in Marine Applications," Water Mist Fire Suppression Workshop, March 1-2, 1993, Proceedings, National Institute of Standards and Technology, NISTIR 5207, Gaithersburg, MD, June 1993.

Appendix B
Draft Standard for Water Mist
Fire Protection System Components

0.0 Introduction

0.1 This document is intended to address minimum fire protection performance, construction, and marking requirements for water mist system components.

0.2 Products employing materials, or having forms of construction differing from the requirements contained herein, may be examined and tested in accordance to the intent of the requirements, and, if found to be substantially equivalent, may be judged to comply with this document.

0.3 Products complying with the text of this document will not necessarily be judged to comply, if, when examined and tested, they are found to have other features which impair the level of safety contemplated by this document.

1.0 Scope

This document contains requirements for components, which comprise shipboard water mist fire protection systems, intended for the protection of machinery spaces, control spaces, accommodation spaces, and service areas. These requirements are intended for the evaluation of components, when fresh or desalinated water is used within the system.

2.0 References

The following standards contain provisions which, through references in this text, constitute provisions of this standard:

ANSI/UL 393: 1991, Underwriters Laboratories Inc., Standard for Indicating Pressure Gauges,

ANSI/UL 448: 1984, Underwriters Laboratories Inc., Standard for Pumps for Fire Protection Service,

ANSI/UL 723: Surface Burning Characteristics of Building Materials,

ANSI/UL 753: 1989, Underwriters Laboratories Inc., Standard for Alarm Accessories for Automatic Water-Supply Control Valves for Fire Protection Service,

ANSI/UL 864: 1991, Underwriters Laboratories Inc., Standard for Control Units for Fire Protection Signaling Systems,

ANSI/UL 1739: 1988, Underwriters Laboratories Inc., Standard for Pilot Operated Pressure Control Valves,

ASTM B117: 1985 Method of Salt Spray (Fog) Testing,

ASTM D395: 1985 Method B of the Standard Test Methods for Rubber Property, Compression Set,

ISO 7-1: 1982, Pipe Threads, where pressure tight joints are made on threads, Part 1: Designation, Dimension and Tolerances,

ISO 37-1977: Rubber, vulcanized - determination of tensile stress-strain properties,

ISO 898-1: 1988, Mechanical properties of fasteners - Part 1: Bolts, screws, and studs,

ISO 889-2: 1980, Mechanical properties of fasteners - Part 2: Nuts, with specified proof load valves,

ISO 6182-6: 1993, Draft Standard for Fire Protection - Automatic Sprinkler Systems, Part 6: Requirements and Methods of Test for Check Valves,

NEMA MG-1: 1978, National Electrical Manufacturers Association Standards for Industrial Control Systems,

NFPA 25: 1992 National Fire Protection Association Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, and

UL 508: 1989, Underwriters Laboratories Inc., Standard for Electric Industrial Control Equipment.

3.0 Definitions

3.1 Accommodation Spaces - Areas where people may gather such as restaurants, dining rooms, lounges, corridors, lavatories, offices, and cabins.

3.2 Conductivity Factor - A measure of the conductance between the nozzle's heat responsive element and the fitting expressed in units of $(m/s)^{0.5}$.

3.3 Control Spaces - Areas such as the bridge, radio room, and emergency power room.

3.4 Corrosion Resistant Material - Materials of bronze, brass, monel metal, austenitic stainless, or plastic.

3.5 Flow Velocity - The rate of water flow through a valve or expressed as the equivalent water velocity through a pipe of the same nominal size as the valve.

3.6 High Risk Areas - Areas in machinery spaces where pressurized flammable or combustible liquids are present which have the potential for leads, and are subject to potential heat or ignition sources.

3.7 Light Hazard Area - Areas where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release expected.

3.8 Low Risk Area - Areas in machinery spaces where flammable or combustible liquids could spread by leakage into high risk areas.

3.9 Machinery Spaces - Engine rooms and cargo pump rooms containing combustible or flammable liquids having fire characteristics no more severe than diesel oil.

3.10 Nozzles

3.10.1 Automatic Nozzle - A thermosensitive device designed to react at a predetermined temperature, by automatically releasing a stream of water and distributing it in a specified pattern and quantity over a designated area.

3.10.2 Coated Nozzle - A nozzle which has a factory applied coating for corrosion protection.

3.10.3 Fast Response Nozzle - an automatic nozzle having a response time index (RTI) less than 50 $(m \bullet s)^{0.5}$ and a conductivity factor (C) less than 1.0.

3.10.4 Fusible Element Nozzle - A nozzle that opens under the influence of heat by the melting of a component.

3.10.5 Glass Bulb Nozzle - A nozzle that opens under the influence of heat by the bursting of the glass (frangible) bulb through pressure resulting from expansion of the fluid enclosed therein.

3.10.6 Multiple Orifice Nozzle - A nozzle having two or more outlet orifices arranged to distribute the water discharge in a specified pattern and quantity for a definite protection area.

3.10.7 Pendent Nozzle - A nozzle that is arranged in such a way that the water stream is directed downward by striking a distribution plate or by nozzle orientation.

3.10.8 Recessed Nozzle - A nozzle of which all or part of the body, other than the inlet thread, is mounted within a recessed housing.

3.10.9 Special Response Nozzle - An automatic nozzle having an average response time index (RTI) between 50 and 80 $(m \bullet s)^{0.5}$ and a conductivity (C) factor less than 1.0.

3.10.10 Standard Response Nozzle - An automatic nozzle having a response time index (RTI) between 80 and 350 $(m \bullet s)^{0.5}$ and a conductivity (C) factor not exceeding 2.0.

3.10.11 Upright Nozzle - A nozzle that is arranged in such a way that the water stream is directed upwards against a distribution plate.

3.11 Ordinary Hazard Area - Area where the quantity and combustibility of contents is moderate, stockpiles of combustibles do not exceed 2.4 m, and fires with moderate rates of heat release are expected.

3.12 Rated Working Pressure - Maximum service pressure at which a hydraulic device, such as a valve, nozzle, or pump, is intended to operate.

3.13 Response Time Index: (RTI) - A measure of nozzle sensitivity expressed as $RTI = tu^{0.5}$, where t is the time constant of the heat responsive element in units of seconds, and u is the gas velocity expressed in meters per second. RTI can be used in combination with the conductivity factor (C) to predict the response of a nozzle in fire environments defined in terms of gas temperature and velocity versus time. RTI has units of $(m \bullet s)^{0.5}$.

3.14 Service Spaces - Areas where a ship's crew may perform their duties, such as galleys, laundry, lockers, storerooms, and baggage rooms.

3.15 Standard Orientation - In the case of symmetrical heat responsive elements, standard orientation is with the air flow perpendicular to both the axis of the nozzle's waterway, and the plane of the frame arms. In the case of nonsymmetrical heat responsive elements, standard orientation is with the air flow perpendicular to both the waterway axis and the plane of the frame arms which produces the shortest response time.

3.16 Water Mist Fire Suppression System - Fire protection system consisting of a water supply, water distribution system and nozzles designed to discharge fine water droplets, from one or more nozzles, to extinguish or control a fire.

3.17 Worst Case Orientation - The orientation which produces the longest response time with the axis of the nozzle waterway perpendicular to the air flow.

4.0 Product Consistency

It shall be the responsibility of the manufacturer to implement a quality control program to ensure that production continuously meets the requirements in the same manner as the originally tested samples.

5.0 General Requirements

5.1 All components, exposed to the water supplying discharge nozzles, shall be made from corrosion resistant materials. All other materials are to be suitable for shipboard use, and have appropriate corrosion protection. Consideration should be given to the effects of corrosive atmospheres, vibration, and intended use, when materials are chosen and the system is installed.

5.2 Electrical components, such as pump controllers and motors, are intended to be installed in areas that are not exposed to corrosive or harsh environments.

5.3 System components, including piping, shall be installed and securely fastened in a manner which will prevent unacceptable movement of the system components.

5.4 Water used in the systems shall be fresh or desalinated. If salt or untreated water is intended to be used as a temporary supplement to the stored fresh or desalinated water supply during extreme or unusual fire conditions, the system shall be designed and equipped with flushing connections, so that all parts of the system can be completely flushed immediately after use.

5.5 Water mist system components, except those covered in separate sections, shall be capable of withstanding exposure to vibration, by not exhibiting physical deterioration when tested in accordance with Section 6.1, and shall comply with the following:

a) remain operable,
b) not cause a risk of injury to persons,
c) no dislodgment of any component or part, and
d) not experience physical deterioration or breakage of any component to the extent that would require repair or replacement. For example, broken welds, malfunctions of operating parts, or abrading or scoring of a pressurized cylinder in excess of 10 percent of the minimum calculated wall thickness are unacceptable.

Exception: A high pressure water mist fire suppression system device, that is floor supported and that is not supplied with a mounting bracket, need not be tested with the attached mounting bracket.

5.6 Water mist system components, except those covered in separate sections, shall comply with the following when exposed to a salt spray corrosive atmosphere described in Section 6.2:

a) water mist suppression system components shall show no evidence of corrosion on any surface, other than corrosion that can be easily wiped off after rinsing with tap water; if any part of the system has a corrosion resistant coating, the coating shall be intact and shall not be removable by rinsing the tap water or rubbing with a finger,
b) no galvanic corrosion shall be visible on the system components,
c) if the system has a pressure gauge, the gauge shall not have moisture inside, and
d) shall operate as intended.

5.7 An elastomer used to provide a water seal or valve seal, other than flange gaskets, shall be tested to determine that it has the following properties when conducted in accordance with ISO 37:

a) As received, the material shall be as follows:

  1) minimum tensile strength of 3.4 MPa for silicone rubber (having the characteristic constituent of poly-organo-siloxane); 10.3 MPa for other elastomers, and
  2) minimum ultimate elongation of 100 percent for silicone rubber and 150 percent for other elastomers.

b) The physical properties, after aging in an air oven at the time and temperature specified in Table 1, shall be at least 60 percent of the original tensile strength and elongation values. The maximum service temperature used to determine the oven time and temperature, is considered to be 60°C unless the product is intended for use at a higher temperature.

5.7.1 It is preferred to conduct the above tests on samples of the original part. The size and shape of a part will determine which of the tests can actually be conducted on the part. In general, a part larger than 25.4 mm inside diameter will be subjected to these tests. If the size of the actual part is less than 25.4 mm or precludes accurate testing, larger samples of similar parts or sheet material made of the same compound are to be subjected to these tests.

5.8 Alarms shall be designed to indicate the location of activation at a manned central location.

Table 1. Oven Aging

Maximum Service Temperature, °C	Oven Time and Temperature, °C
60	70 hours at 100
75	168 hours at 100
80	168 hours at 113
90	168 hours at 121
105	168 hours at 136
115	1440 hours at 123
125	1440 hours at 133
135	1440 hours at 143
145	1440 hours at 153
150	1440 hours at 158
155	1440 hours at 164
165	1440 hours at 174
175	1440 hours at 184
185	1440 hours at 194
195	1440 hours at 204
200	1440 hours at 210
210	1440 hours at 220
220	1440 hours at 230
230	1440 hours at 240
240	1440 hours at 250
250	1440 hours at 260

5.9 Pipe and fitting threads shall conform to the applicable requirements of the International Standard for Pipe Threads, ISO 7-1: 1982.

Exception: National Standards may be used if International Standards are not applicable.

6.0 General Requirement Test Methods

6.1 Vibration Test

6.1.1 Representative samples of the water mist system components are to be mounted in their securing bracket, if normally provided, or in a standard mounting fixture, and secured to the test fixture of the vibration test apparatus in the manner in which the components are intended to be installed.

6.1.2 The test samples are to be subjected to vibration tests in each of the three rectilinear orientation axes: horizontal, lateral, and vertical. The tests specified in 6.1.3 and 6.1.4 are to be completed in one plane or vibration before the samples are tested in another plane.

6.1.3 The test samples are to be vibrated over the range of 10 to 60 Hertz at discrete frequency intervals of 2 Hertz at the table displacement specified in Table 2. The vibration at each frequency is to be maintained for 5 minutes.

Table 2. Amplitude of Vibration

Frequency of Vibration, Hertz	Table Displacement (mm)	Amplitude (mm)
10-18	1.52 ± 0.15	0.76 ± 0.08
20-38	1.02 ± 0.10	0.51 ± 0.05
40-60	0.51 ± 0.05	0.25 ± 0.03

6.1.4 The test samples are to be vibrated for 2 hours at the frequency that produced maximum resonance during the vibration described in 6.1.3 or, if no resonance had been observed, at a frequency of 60 Hertz. The table displacement is to be as specified in Table 2.

6.1.5 For these tests, "amplitude" is defined as the maximum displacement of sinusoidal motion from position of rest, or as one-half of the total table displacement. " Resonance" is defined as the maximum magnification of the applied vibration.

6.2 Salt Spray Corrosion Test

6.2.1 The test samples are to be supported vertically and exposed to salt spray (fog) using the methods specified in Salt Spray (Fog) Testing, ASTM B117. The apparatus used for salt spray exposure is to consist of a fog chamber, 1.2 by 0.8 by 0.9 m inside dimensions, having a salt solution reservoir, a supply of conditioned compressed air, a dispersing tower for producing a salt fog, sample supports, provision for heating the chamber, and necessary means of control. The dispersion tower is to be located in the center of the chamber and is to be supplied with salt solution and with warmed, humidified air at a pressure between 117 and 131 kPa, to disperse the salt solution in the form of a fine mist or fog throughout the interior of the chamber. The temperature within the chamber is to be maintained between 33.3 and 36.1°C. Condensate accumulation on the cover of the chamber is not to be permitted to drop onto the test samples, and drops of the solution that fall from the samples are not be recirculated, but are to be removed through a drain located in the floor of the chamber.

6.2.2 The salt solution is to consist of 20 percent (by weight) of common salt (sodium chloride) and distilled water and the test duration is to be 240 hours. The pH value of this solution as collected after being sprayed in the test apparatus is to be between 6.5 and 7.2, and the specific gravity is to be between 1.126 and 1.157 at 35.30°C.

7.0 Water Mist Nozzle Requirements

7.1 Dimensions

Nozzles shall be provided with a nominal 6 mm (1/4 in.) or larger nominal inlet thread. The dimensions of all threaded connections should conform to International Standards where applied. National Standards may be used if International Standards are not applicable.

7.2 Nominal Release Temperatures

7.2.1 The nominal release temperatures of automatic glass bulb nozzles shall be as indicated in Table 3.

7.2.2 The nominal release temperatures of fusible automatic element nozzles shall be specified in advance by the manufacturer and verified in accordance with 7.3. They shall be determined as a result of the nominal release temperature test. See Section 8.6.1. Nominal release temperatures shall be within the ranges specified in Table 3.

7.2.3 The nominal release temperature that is to be marked on the nozzle shall be that determined when the nozzle is tested in accordance with 8.6.1, taking into account the specifications of 7.3.

Table 3. Nominal Release Temperature

(Values in Degrees Celsuis)

1	2	3	4
Glass Bulb Nozzles		**Fusible Element Nozzles**	
Nominal Release Temperature	**Liquid Color Code**	**Nominal Release Temperature**	**Frame Color Code +**
57	orange	57 to 77	uncolored
68	red	80 to 107	white
79	yellow	121 to 149	blue
93-100	green	163 to 191	red
121-141	blue	204 to 246	green
163-182	mauve	260 to 343	orange
204-343	black		

Note: + - not required for decorative nozzles

7.3 Operating Temperatures (see 8.6.1)

Automatic nozzles shall open within a temperature range of

$$X \pm (0.035X + 0.62)\ °C$$

where X is the nominal release temperature.

7.4 Water Flow and Distribution

7.4.1 Flow Constant (See 8.10)

7.4.1.1 The flow constant K for nozzles is given by the formula:

$$K = \frac{Q}{p^{0.5}}$$

where: p is the pressure in bars;
Q is the flow rate in liters per minute.

7.4.1.2 The value of K shall be determined, using the test method of 7.2.10, and published in the Manufacturer's Design and Installation Instructions.

7.4.2 Water Distribution (See 8.11)

Nozzles which have complied with the requirements of the fire test shall be used to determine the effective nozzle discharge characteristics when tested in accordance with 8.11.1. These characteristics shall be published in the Manufacturer's Design and Installation Instructions.

7.4.3 Water Droplet Size and Velocity (See 8.11.2)

The water droplet size distribution, and droplet velocity distribution, shall be determined in accordance with 8.11.2 for each design nozzle at the minimum and maximum design water flow rate, and minimum and maximum air flow rate (when used), as part of the identification of the discharge characteristics of the nozzles, which have demonstrated compliance with the fire test.

7.5 Function (See 8.5)

7.5.1 When tested in accordance with 8.5, the nozzle shall open and, within 5 seconds after the release of the heat responsive element, shall operate satisfactorily by complying with the requirements of 8.10. Any lodging of released parts shall be cleared within 60 seconds of release for standard response heat responsive elements, and within 10 seconds of release for fast and special response heat responsive elements, and the nozzle shall then comply with the requirement of 8.10.

7.5.2 The nozzle discharge components shall not sustain significant damage as a result of the functional test specified in 8.5.6, and shall have the same flow constant range as previously tested in 8.10 and calculated per 7.4.1.

7.6 Strength of Body (See 8.3)

The nozzle body shall not show permanent elongation of more than 0.2% between the load-bearing points, after being subjected to twice the average service load as determined using the method of 8.3.1.

7.7 Strength of Release Element

7.7.1 Glass Bulbs (See 8.9.1)

The average strength of glass bulb elements shall be at least six times the average service load of the nozzle when tested by the method specified in 8.9.1.

7.7.2 Fusible Elements (See 8.9.2)

Fusible heat-responsive elements in the ordinary temperature range shall be designed to:

- sustain a load of 15 times its design load corresponding to the maximum service load measured in 8.3.1 for a period of 100 hours, or
- demonstrate the ability to sustain the design load when tested in accordance with 8.9.2.

7.8 Leak Resistance and Hydrostatic Strength (See 8.4)

7.8.1 A nozzle shall not show any sign of leakage when tested by the method specified in 8.4.1.

7.8.2 A nozzle shall not rupture, operate, or release any parts when tested by the method specified in 8.4.2.

7.9 Heat Exposure

7.9.1 Glass Bulb Nozzles (See 8.7.1)

There shall be no damage to the glass bulb element when the nozzle is tested by the method specified in 8.7.1.

7.9.2 All Uncoated Nozzles (See 8.7.2)

Nozzles shall withstand exposure to increased ambient temperature without evidence of weakness or failure, when tested by the method specified in 8.7.2.

7.9.3 Coated Nozzles (See 8.7.3)

In addition to meeting the requirement of 8.7.2 in an uncoated version, coated nozzles shall withstand exposure to ambient temperatures, without evidence of weakness or failure of the coating, when tested by the method specified in 8.7.3.

7.10 Thermal Shock (See 8.8)

Glass bulb nozzles shall not be damaged when tested by the method specified in 8.8. Proper operation is not considered as damage.

7.11 Corrosion

7.11.1 Stress Corrosion (See 8.12.1 and 8.12.2)

When tested in accordance with 8.12.1, all brass nozzles shall show no fractures which could affect their ability to function as intended and satisfy other requirements.

When tested in accordance with 8.12.2, stainless steel parts of water mist nozzles shall show no fractures or breakage which could affect their ability to function as intended and satisfy other requirements.

7.11.2 Sulfur Dioxide Corrosion (See 8.12.3)

Nozzles shall be sufficiently resistant to sulfur dioxide saturated with water vapor when conditioned in accordance with 8.12.2. Following exposure, five nozzles shall operate when functionally tested at their minimum flowing pressure (see 7.5.1 and 7.5.2). The remaining five samples shall meet the dynamic heating requirements of 7.14.

7.11.3 Salt Spray Corrosion (See 8.12.4)

Coated and uncoated nozzles shall be resistant to salt spray when conditioned in accordance with 8.12.4. Following exposure, the samples shall meet the dynamic heating requirements of 7.14.2.

7.11.4 Moist Air Exposure (See 8.12.5)

Nozzles shall be sufficiently resistant to moist air exposure and shall satisfy the requirements of 7.14.2 after being tested in accordance with 8.12.5.

7.12 Integrity of Nozzle Coatings

7.12.1 Evaporation of Wax and Bitumen Used for Atmospheric Protection of Nozzles (See 8.13.1)

Waxes and bitumens used for coating nozzles shall not contain volatile matter in sufficient quantities to cause shrinkage, hardening, cracking or flaking of the applied coating. The loss in mass shall not exceed 5% of that of the original sample when tested by the method in 8.13.1.

7.12.2 Resistance to Low Temperatures (See 8.13.2)

All coatings used for nozzles shall not crack or flake when subjected to low temperatures by the method in 8.13.2.

7.12.3 Resistance to High Temperature (See 7.9.3)

Coated nozzles shall meet the requirements of 7.9.3.

7.13 Water Hammer (See 8.15)

Nozzles shall not leak when subjected to pressure surges from 4 bar to twice the rated pressure for operating pressures up to 100 bars, and 1.5 times the rated pressure for pressures greater than 100 bar. They shall show no signs of mechanical damage when tested in accordance with 8.15, and shall operate within the parameters of 7.5.1 at the minimum design pressure.

7.14 Dynamic Heating (See 8.6.2)

7.14.1 Automatic nozzles intended for installation in accommodation spaces shall comply with fast response requirements. Automatic nozzles intended for installation in service, machinery or control spaces shall comply with standard or special requirements for RTI and C limits shown in Figure 1, when tested in the standard orientation as described in 8.6.2. Maximum and minimum RTI values for all data points calculated using C for the fast and standard response nozzles shall fall within the appropriate category shown in Figure 1. Special response nozzles shall have an average RTI value, calculated using C, between 50 and 80 with no value less than 40 or more than 100. When tested in the worst case orientation (± 30°), as described in Section 8.6.2, the RTI shall not exceed 130% of the value of RTI in the standard orientation.

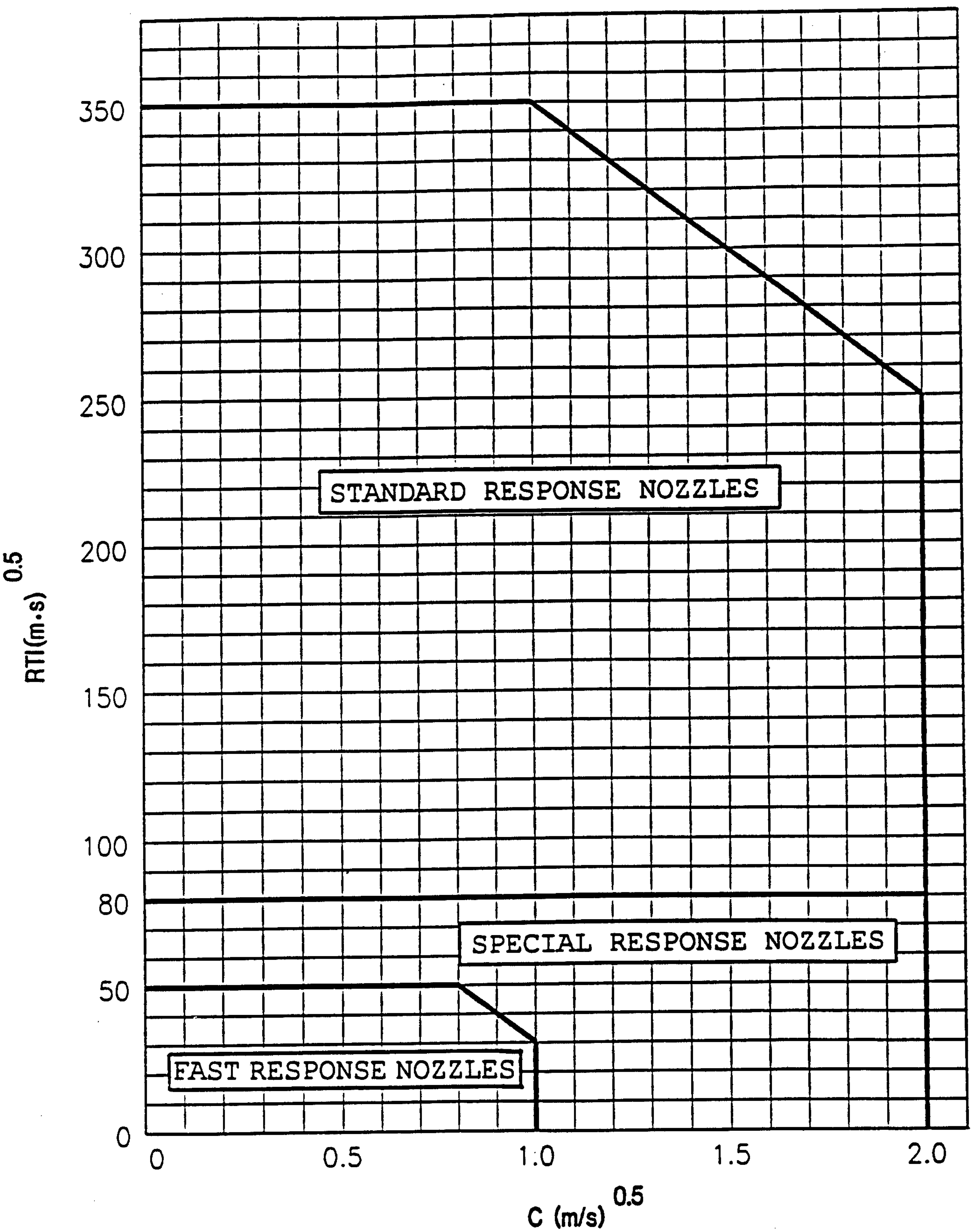

Figure 1. RTI and C Limits for Standard Orientation

7.14.2 After exposure to the corrosion test described in Section 7.11.2, 7.11.3 and 7.11.4, nozzles shall be tested in the standard orientation as described in Section 8.6.2.1 to determine the post exposure RTI. All post exposure RTI values shall not exceed the limits shown in Figure 1 for the appropriate category. In addition, the average RTI value shall not exceed 130% of the pre-exposure average value. All post exposure RTI values shall be calculated as in Section 8.6.2.3 using the pre-exposure conductivity factor (C).

7.15 Resistance to Heat (See 8.14)

Open nozzles shall be sufficiently resistant to high temperatures when tested in accordance with 8.14. After exposure, the nozzle shall not show:

1) visual breakage or deformation, and
2) no changes in the discharge characteristics of the Water Distribution Test (see 7.4.2).

7.16 Resistance to Vibration (See 8.16)

Nozzles shall be able to withstand the effects of vibration without deterioration of their performance characteristics when tested in accordance with 8.16. After the vibration test of 8.16, nozzles shall show no visible deterioration and shall meet the requirements of 7.5 and 7.8.

7.17 Impact Test (See 8.17)

Nozzles shall have adequate strength to withstand impacts associated with handling, transport and installation without deterioration of their performance or reliability. Resistance to impact shall be determined in accordance with 8.1.

7.18 Fire Tests

7.18.1 Machinery Spaces (See 8.18)

7.18.1.1 When tested as described in 8.18, a water mist system intended for the protection of Category A engine rooms shall extinguish the test fires and prevent reignition.

7.18.1.2 Class 1, 2, and 3 Category A engine rooms are characterized in Table 4.

7.18.2 Accommodation Spaces (See 8.19)

7.18.2.1 Water mist fire suppression systems intended for the protection of accommodation spaces up to 12 m^2 in area shall comply with the cabin fire test methods described in 8.19.1. If protection is desired for passenger cabins greater than 12 m^2 in area, the fire tests described in 8.19.2 shall be conducted.

> **Note:** For passenger cabins greater than 12 m^2 in area, the spacing and nozzle arrangements used in the public space fire tests, for the appropriate ceiling height, may be used.

7.18.2.2 Water mist nozzles installed for the protection of passenger cabins and corridors in accordance with 8.19.1 shall comply with the following requirements:

A) Prevent flashover of passenger cabin or corridor except in Fire Test 8.19.1.6.1(4),

B) Comply with the temperature and rate of heat release criteria described in Table 5.

Table 4. Classification of Category A Engine Rooms

Class	Typical Engine Facts	Typical Net Volume	Typical Oil Flow & Pressure in Fuel and Lubrication System	Fire Test Conditions
1	Auxiliary engine room, small main machinery or purifier room, etc.	500 m^3	Fuel: Low pressure 0.15-0.20 kg/s 3-6 bar High pressure 0.02 kg/s 200-300 bar Lubrication oil: 3-5 bar Hydraulic oil: 150 bar	The test should be performed in a 80-100 m^2 room with 5 m ceiling height and ventilation through a 4 m^2 door opening. Fires and engine mock-up according to Table 9, Page B-32
2	Main diesel machinery in medium sized ships as ferries	3000 m^3	Fuel: Low pressure 0.4-0.6 kg/s at 3-8 bar High pressure 0.030 kg.s at 250 bar Lubrication oil: 3-5 bar Hydraulic oil: 150 bar	The test should be performed in a fire test hall with a minimum floor area of 300 m^2 and without any restrictions in air supply for the test fires. If the system is restricted to fire protection of medium speed engines only, a ceiling is permitted of 5 m height. Test fires according to Table 9, Page B-32.
3	Main diesel machinery in large ships as oil tankers and container ships	>3000 m^3	Fuel: Low pressure 0.7-1.0 kg/s at 3-8 bar High pressure 0.20 kg/s Lubrication oil: 3-5 bar Hydraulic oil: 150 bar	The test should be performed in a fire test hall with minimum floor area of 300 m^2 and without any restrictions in air supply for the test fires.

Table 5. **Performance Criteria for 12 M2 Cabin/Corridor Fire Test**

Test	Maximum RHR (kW)	RHR 60 second after activation (kW)	Maximum temperature in Cabin *	Temperature in Cabin * 60 seconds after activation (°C)	Maximum temperature, Location A * in corridor (°C)	Temperature in corridor location A* 30 seconds after activation (°C)
Fire arranged in the Cabin						
A	250	100	300	150	250	100
B	300	**	600	200	500	150
C	**		600	300	500	150
Fire arranged in the Corridor						
D	**	**	-	-	300	100

* The temperature measured 10 cm below the ceiling.

** No RHR criteria given. Activation of sprinkler(s) in the corridor restrains the outflow of smoke from the fire which affects the RHR measurements.

7.18.3 Public Spaces (See 8.20)

7.18.3.1. Water mist nozzles installed to protect light hazard areas of public spaces shall comply with the following requirements:

A. Suppress or control the fire test described in 8.20.1.1, and

B. Prevent reignition of the fuel package following a maximum water discharge duration of 10 minutes. Unburnt materials shall be present at the end of the test.

7.18.3.2 Water mist nozzle installed to protect ordinary hazard areas of public spaces, shall comply with the performance criteria described in 8.20.2.6, when tested in accordance with 8.20.2.1 through 8.20.2.5.

7.19 Lateral Discharge (See 8.21)

Nozzles shall not prevent the operation of adjacent automatic nozzles when tested in accordance with 8.21.

7.20 Thirty (30) Day Leakage Resistance (See 8.22)

Nozzles shall not leak, sustain distortion or other mechanical damage when subjected to twice the rated pressure for 30 days. Following exposure, the nozzles shall satisfy the test requirements of 8.22.

7.21 Vacuum Resistance (See 8.23)

Nozzles shall not exhibit distortion, mechanical damage or leakage after being subjected to the test in 8.23.

7.22 Water Shield

7.22.1 Angle of Protection (See 8.24.1)

Water shields shall provide an "angle of protection" of 45° or less, for the heat responsive element, against direct impingement of run-off water from the shield caused by discharge from sprinklers at higher elevations. Compliance with this requirement shall be determined in accordance with 8.24.1.

7.22.2 Rotation (See 8.24.2)

Rotation of the water shield shall not alter the sprinkler service load when evaluated in accordance with 8.24.2.

8.0 Methods of Tests

The following tests shall be conducted for each type of nozzle:

1) Before testing, precise drawings of parts and the assembly shall be submitted together with the appropriate specifications (using SI units).
2) Tests shall be carried out at an ambient temperature of (20, +5, -0) °C, unless other temperatures are indicated. Unless otherwise stated, the tolerances in Appendix B shall apply.

8.1 General

Nozzles shall be tested with all the components required by their design and intended installation.

8.2 Visual Examination

Before testing, nozzles shall be examined visually with respect to the following points:

a) marking,
b) conformity of the nozzles with the manufacturer's drawings and specifications, and
c) obvious defects.

8.3 Body Strength Test

8.3.1 The service load shall be measured on 5 automatic nozzles by securely installing each nozzle, at room temperature, in a tensile/compression test machine, and applying a force caused by application of the rated pressure.

An indicator capable of reading deflection to an accuracy of 0.01 mm shall be used to measure any change in length of the nozzle between its load bearing points. Movement of the nozzle shank thread in the threaded bushing of the test machine shall be avoided or taken into account.

The hydraulic pressure and load is then released, and the heat responsive element is then removed by a suitable method. When the nozzle is at room temperature, a second measurement is to be made using the indicator.

An increasing mechanical load to the nozzle is then applied at a rate not exceeding 500 N/minute, until the indicator reading at the load bearing point initially measured returns to the initial value achieved under hydrostatic load. The mechanical load necessary to achieve this shall be recorded as the service load. This test shall be conducted on five specimens and the mean of the results shall be taken as the "average service load".

8.3.2 The applied load is then progressively increased at a rate not exceeding 500 N/minute on each of the five specimens until twice the average service load has been applied. Maintain this load for 15 ± 5 seconds.

The load is then removed and any permanent elongation as defined in 7.6 is recorded.

8.4 Leak Resistance and Hydrostatic Strength Tests (See 7.8)

8.4.1 Twenty nozzles shall be subjected to a water pressure of twice their rated pressure. The pressure is increased from 0 bar to twice rated pressure, maintained at twice rated pressure for a period of 3 minutes, and then decreased to 0 bar. After the pressure has returned to 0 bar, it is increased to the minimum operating pressure specified by the manufacturer in not more than 5 seconds. The pressure is to be maintained for 15 seconds and then increased to rated pressure and maintained for 15 seconds.

8.4.2 Following the test of 8.4.1, the twenty nozzles shall be subjected to an interval hydrostatic pressure of four times the rated pressure. The pressure is increased from 0 bar to four times the rated pressure, and held there for a period of 1 minute. The nozzle under test shall not rupture, operate or release any of its operating parts during the pressure increase nor while being maintained at four times the rated pressure for 1 minute.

8.5 Functional Test (See 7.5)

8.5.1 Nozzles, having nominal release temperatures less than 78°C, shall be heated in an oven. While being heated, they shall be subjected to each of the water pressures specified in 8.5.3 applied to their inlet. The temperature of the oven shall be increased to 400 ± 20°C in 3 minutes measured in close proximity to the nozzle.

8.5.2 Nozzles having nominal release temperatures exceeding 78°C shall be heated using a suitable heat source. Heating shall continue until the nozzle has operated.

8.5.3 Eight nozzles shall be tested in each normal mounting position, and at pressures equivalent to the minimum discharge pressure, the rated pressure, and at the mid-point pressure. The flowing pressure shall be at least 75% of the initial operating pressure.

8.5.4 If lodging occurs in the release mechanism at any pressure level and mounting position, 24 more nozzles shall be tested in that mounting position and at that pressure. The total number of nozzles in which lodgment occurs shall not exceed 1 in the 32 tested at that pressure and in that mounting position.

8.5.5 Lodgment is considered to have occurred when one or more of the released parts lodge in the discharge assembly in such a way as to cause the water distribution to be altered for a period of more than 1 minute.

8.5.6 In order to check the strength of the deflector, three nozzles shall be submitted to the functional test in each normal mounting position at the rated pressure. The water shall be allowed to flow at the maximum rated pressure for a period of 15 minutes.

8.6 Heat Responsive Element Operating Characteristics

8.6.1 Operating Temperature Test (See 7.3)

Ten nozzles shall be heated from room temperature to 20 to 22°C below their nominal release temperature. The rate of increase of temperature shall not exceed 20°C/minute, and the temperature shall be maintained for 10 minutes. The temperature shall then be increased at a rate between 0.4°C/minute to 0.7°C/minute until the nozzle opens or the glass bulb bursts.

The nominal release temperature shall be ascertained with equipment having an accuracy of ± 1.5%.

The test shall be conducted in a water bath for nozzles or separate glass bulbs having nominal release temperatures less than or equal to 80°C. A suitable oil shall be used for higher-rated release elements. The liquid bath shall be constructed in such a way that the temperature deviation within the test zone does not exceed 0.5%, or 0.5°C, whichever is the greater.

8.6.2 Dynamic Heating Test (See 7.4)

8.6.2.1 Plunge Test

Tests shall be conducted to determine the standard and worst cast orientations. Ten additional plunge tests shall be performed at both of the identified orientations except that the worst case orientation may be tested ± 30° from the worst case orientation. The RTI is calculated as described in 8.6.2.3 and 8.6.2.4 for each orientation, respectively. The plunge tests are to be conducted using a brass nozzle mount designed such that the mount or water temperature rise does not exceed 2°C for the duration of an individual plunge test up to a response time of 55 seconds. (The temperature shall be measured by a thermocouple heatsinked and embedded in the mount not more than 8 mm radially outward from the root diameter of the internal thread or by a thermocouple located in the water at the center of the nozzle inlet.) If the response time is greater than 55 seconds, then the mount or water temperature in degrees Celsius shall not increase more than 0.036 times the response time in seconds for the duration of an individual plunge test.

The nozzle under test shall have 1 to 1.5 wraps of PTFE sealant tape applied to the nozzle threads. It shall be screwed into a mount to a torque of 15 ± 3 Nm. Each nozzle is to be mounted on a tunnel test section cover and maintained in a conditioning chamber to allow the nozzle and cover to reach ambient temperature for a period of not less than 30 minutes.

At least 25 ml of water, conditioned to ambient temperature, shall be introduced into the nozzle inlet prior to testing. A timer accurate to ± 0.01 second with suitable measuring devices to sense the time between when the nozzle is plunged into the tunnel and the time it operates shall be utilized to obtain the response time.

A tunnel shall be utilized with air flow and temperature conditions[1] at the test section (nozzle location) selected from the appropriate range of conditions shown in Table 6. To minimize radiation exchange between the sensing element and the boundaries confining the flow, the test section of the apparatus shall be designed to limit radiation effects to within ± 3% of calculated RTI values[2].

The range of permissible tunnel operating conditions is shown in Table 6. The selected operating condition shall be maintained for the duration of the test with the tolerances as specified by footnotes 4 and 5 in Table 6.

8.6.2.2 Determination of Conductivity Factor (C)

The conductivity factor (C) shall be determined using the prolonged plunge test (see 8.6.2.2.1) or the prolonged exposure ramp test (see 8.6.2.2.2).

8.6.2.2.1 Prolonged Plunge Test

The prolonged plunge test is an iterative process to determine C and may require up to twenty nozzle samples. A new nozzle sample must be used for each test in this section, even if the sample does not operate during the prolonged plunge test.

The nozzle under test shall have 1 to 1.5 wraps of PTFE sealant tape applied to the nozzle threads. It shall be screwed into a mount to a torque of 15 + 3 Nm. Each nozzle is to be mounted on a tunnel test section cover and maintained in a conditioning chamber to allow the nozzle and cover to reach ambient temperature for a period of not less than 30 minutes. At least 25 ml of water, conditioned to ambient temperature, shall be introduced into the nozzle inlet prior to testing.

A timer accurate to ± 0.01 seconds with suitable measuring devices to sense the time between when the nozzle is plunged into the tunnel and the time it operates shall be utilized to obtain the response time.

The mount temperature shall be maintained at 20 ± 0.5°C for the duration of each test. The air velocity in the tunnel test section at the nozzle location shall be maintained with ± 2% of the selected velocity. Air temperature shall be selected and maintained during the test as specified in Table 7.

The range of permissible tunnel operating conditions is shown in Table 7. The selected operating condition shall be maintained for the duration of the test with the tolerances as specified in Table 7.

To determine C, the nozzle is immersed in the test stream at various air velocities for a maximum of 15 minutes[3]. Velocities are chosen such that actuation is bracketed between two successive test velocities. That is, two velocities must be established such that at the lower velocity (u_l)

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[1] Tunnel conditions shall be selected to limit maximum anticipated equipment error to 3%.

[2] A suggested method for determining radiation effects is by conducting comparative plunge tests on a blackened (high emissivity) metallic test specimen and a polished (low emissivity) metallic test specimen.

[3] If the C is determined to be less than 0.5 $(m \bullet s)^{0.5}$ a C of 0.25 $(m \bullet s)^{0.5}$ shall be assumed for calculating RTI value.

actuation does not occur in the 15 minute test interval. At the next higher velocity (u_h), actuation must occur within the 15 minute time limit. If the nozzle does not operate at the highest velocity, select an air temperature from Table 7 for the next higher temperature rating.

Table 6. Plunge Over Test Conditions

	Air Temperature Ranges [4]			Velocity Ranges [5]		
Normal Temperature (°C)	**Standard Response (°C)**	**Special Response (°C)**	**Fast Response (°C)**	**Standard Response m/s**	**Special Response m/s**	**Fast Response Nozzle m/s**
57 to 77	191 to 203	129 to 141	129 to 141	2.4 to 2.6	2.4 to 2.6	1.65 to 1.85
79 to 107	282 to 300	191 to 203	191 to 203	2.4 to 2.6	2.4 to 2.6	1.65 to 1.85
121 to 149	382 to 432	282 to 300	282 to 300	2.4 to 2.6	2.4 to 2.6	1.65 to 1.85
163 to 191	382 to 432	382 to 432	382 to 432	3.4 to 2.6	2.4 to 2.6	1.65 to 1.85

[4] The selected air temperature shall be known and maintained constant within the test section throughout the test to an accuracy of ± 1°C for the air temperature range of 129 to 141°C within the test section and within ± 2°C for all other air temperatures.

[5] The selected air velocity shall be known and maintained constant throughout the test to an accuracy of ± 0.03 m/s for velocities of 1.65 to 1.85 and 2.4 and 2.6 m/s and ± 0.04 m/s for velocities of 3.4 and 3.6 m/s.

Table 7. Plunge Oven Test Conditions for Conductivity Determinations

Nominal NozzleTemperature (°C)	Oven Temperature (°C)	Maximum Variation of Air Temperature During Test (°C)
57	85 to 91	± 1.0
58 to 77	124 to 130	± 1.5
78 to 107	193 to 201	± 3.0
121 to 149	287 to 295	± 4.5
163 to 191	402 to 412	± 6.0

Test velocity selection shall insure that:

$$(U_H / U_L)^{0.5} \leq 1.1$$

The test C is the average of the values calculated at the two velocities using the following equation:

$$C = (\Delta Tg / \Delta Tea - 1)\, u^{0.5}$$

where

Δ Tg	Actual gas (air) temperature minus the mount temperature (Tm) in °C.
Δ Tea	Mean liquid bath operating temperature minus the mount temperature (Tm) in °C.
u	Actual air velocity in the test section in m/s.

The nozzle C is determined by repeating the bracketing procedure three times and calculating the numerical average of the three C values. This nozzle C value is used to calculate all standard orientation RTI values for determining compliance with 7.14.1.

8.6.2.2.2 Prolonged Exposure Ramp Test

The prolonged exposure ramp test for the determination of the parameter C shall be carried out in the test section of a wind tunnel and with the requirements for the temperature in the nozzle mount as described for the dynamic heating test. A preconditioning of the nozzle is not necessary.

Ten samples shall be tested of each nozzle type, all nozzles positioned in standard orientation. The nozzle shall be plunged into an air stream of a constant velocity of 1 m/s ± 10% and an air temperature at the nominal temperature of the nozzle at the beginning of the test.

The air temperature shall then be increased at a rate of 1 ± 0.25°C/minute until the nozzle operates. The air temperature, velocity and mount temperature shall be controlled from the initiation of the rate of rise and shall be measured and recorded at nozzle operation. The C value is determined using the same equation as in 8.6.2.2.1 as the average of the ten test values.

8.6.2.3 RTI Value Calculation

The equation used to determine the RTI value is as follows:

$$\mathrm{RTI} = \frac{-t_r (u)^{0.5} (1 + C / u^{0.5})}{\ln\left[\ 1 - \Delta T_{ea} (1 + C / (u)^{0.5} / \Delta T_g\ \right]}$$

Where:

t_r	response time of nozzles in seconds
u	actual air velocity in the test section of the tunnel in m/s from Table 6
ΔT_{ea}	mean liquid bath operating temperature of the nozzle minus the ambient temperature in °C
ΔT_g	actual air temperature in the test section minus the ambient temperature in °C
C	Conductivity factor as determined in 8.6.2.2.

8.6.2.4 Determination of Worst Case Orientation RTI

The equation used to determine the RTI for the worst case orientation is as follows:

$$RTI_{wc} = \frac{-t_{r-wc}(u)^{0.5}[1 + C(RTI_{wc} / RTI) / (u)^{0.5}]}{\ln\{1 - \Delta T_{ea}[1 + C(\ RTI_{wc} / RTI\ ) / (u)0.5] / \Delta T_g\}}$$

where:

t_{r-wc} response time of the nozzles in seconds for the worst case orientation

All variables are known at this time per the equation in Paragraph 8.6.2.3 except RTI_{wc} (Response Time Index for the worst case orientation) which can be solved by iteration of the above equation.

In the case of fast response nozzles, if a solution for the worse case orientation RTI is unattainable, plunge testing in the worst case orientation shall be repeated using the plunge test conditions under Special Response shown in Table 6.

8.7 Heat Exposure Test

8.7.1 Glass Bulb Nozzles (See 7.9.1)

Glass bulb nozzles having nominal release temperatures less than or equal to 80°C shall be heated in a water bath from a temperature of (20 ± 5)°C to (20 ± 2)°C below their nominal release temperature. The rate of increase of temperature shall not exceed 20°C/minute. Refined oil shall be used for higher temperature rated release elements.

This temperature shall then be increased at a rate of 1°C/minute to the temperature at which the gas bubble dissolves, or to a temperature 5°C lower than the nominal operating temperature, whichever is lower. Remove the nozzle from the liquid bath and allow it to cool in air until the gas bubble has formed again. During the cooling period, the pointed end of the glass bulb (seal end) shall be pointing downwards. This test shall be performed four times on each of four nozzles.

8.7.2 All Uncoated Nozzles (See7.9.2)

Twelve uncoated nozzles shall be exposed for a period of 90 days to a high ambient temperature that is 11°C below the nominal rating or at the temperature shown in Table 8, whichever is lower, but not less than 49°C. If the service load is dependent on the service pressure, nozzles shall be tested under the rated pressure. After exposure, four of the nozzles shall be subjected to the tests specified in 8.4.1, four nozzles to the test of 8.5.1, 2 at the minimum operating pressure and 2 at the maximum operating pressure, and four nozzles to the requirements of 7.3. If a nozzle fails the test, eight additional nozzles shall be tested as described above and subjected to the test in which the failure was recorded. All eight nozzles shall comply with the test requirements.

Table 8. Test Temperatures for Coated and Uncoated Nozzles

Values in Degrees Celsius		
Nominal Release Temperature	**Uncoated Nozzle Temperature**	**Coated Nozzle Test Temperature**
57-60	49	49
61-77	52	49
78-107	79	66
108-149	121	107
150-191	149	149
192-246	191	191
247-302	246	246
303-343	302	302

8.7.3 Coated Nozzles (See 7.9.3)

In addition to the test exposure of 8.7.2 in an uncoated version, twelve coated nozzles shall be exposed to the test of 8.7.2 using the temperatures shown in Table 8 for coated nozzles.

The test shall be conducted for 90 days. During this period, the sample shall be removed from the oven at intervals of 7 days and allowed to cool for 2 to 4 hours. During this cooling period, the sample shall be examined. After exposure, four of the nozzles shall be subjected to the tests specified in 8.4.1, four nozzles to the test of 8.5.1, 2 at the minimum operating pressure and 2 at the maximum operating pressure, and four nozzles to the requirements of 7.3.

8.8 Thermal Shock Test for Glass Bulb Nozzles (See 7.10)

Before starting the test, condition at least 24 nozzles at room temperature of 20 to 25°C for at least 30 minutes.

The nozzles shall be immersed in a bath of liquid, the temperature of which shall be 10 ± 2°C below the nominal release temperature of the nozzles. After 5 minutes, the nozzles are to be removed from the bath and immersed immediately in another bath of liquid, with the bulb seal downwards, at a temperature of 10 ± 1°C. Then test the nozzles in accordance with 8.5.1.

8.9 Strength Test for Release Elements

8.9.1 Glass Bulbs (See 7.7.1)

At least 15 sample bulbs in each temperature rating and each bulb type shall be positioned in their normal mounting device and shall be subjected to a uniformly increasing force at a rate not exceeding 250 N/s in the test machine. Record the crush force for each bulb and calculate the average crush force. The mounting device may be reinforced externally to prevent its collapse.

8.9.2 Fusible Elements (See 7.7.2)

Subject fusible heat-responsive elements to loads in excess of the maximum design load L_d, which will produce failure within and after 1000 hours. At least 10 samples shall be subjected to different loads up to 15 times the maximum design load. Abnormal failures shall be rejected. A full logarithmic regression analysis using the method of least squares shall be performed. From this, the load at 1 hour, L_o, and the load at 1000 h, L, is calculated where:

$$L_d \leq 1.02 L_m{}^2 / L_o$$

These tests shall be conducted at an ambient temperature of 20 ± 3°C. For sample calculations, see Appendix A.

8.10 Water Flow Test (See 7.4.1)

The nozzle shall be mounted with a pressure gauge on a supply pipe. The water flow shall be measured at pressures ranging from the minimum operating pressure to the maximum operating pressure at intervals of 10% of the operating range. In one series of tests, the pressure shall be increased from zero to each value and, in the next series, the pressure shall be decreased from the rated pressure to each value. The flow constant, K, shall be averaged from each series of readings, i.e., increasing pressure and decreasing pressure, and, in each case, shall be within 10% of the average K-value. During the test, pressures shall be corrected for differences in height between the gauge and the outlet orifice of the nozzle.

8.11 Water Distribution and Droplet Size Tests

8.11.1 Water Distribution (See 7.4.2)

The tests shall be conducted in a test chamber of minimum dimensions 7 m x 7 m. For standard automatic nozzles, install a single open nozzle, and then four open nozzles of the same type arranged in a square, at maximum spacings specified by the manufacturer, on piping prepared for this purpose. For pilot type nozzles, install a single nozzle and then the maximum number of slave nozzles at their maximum spacings, specified in the Manufacturer Design and Installation Instructions.

The distance between the ceiling and the distribution plate of upright nozzles shall be 50 mm. In the case of pendent nozzles, the distance shall be 275 mm.

Recessed-type nozzles shall be mounted in a false ceiling of dimensions not less than 6 m x 6 m and arranged symmetrically in the test chamber. The nozzles shall be fitted directly into the horizontal pipework by means of "T" or elbow fittings.

The water discharge distribution in the protected area below a single nozzle and between the multiple nozzles, shall be collected and measured by means of square measuring containers 500 mm on a side. The distance between the ceiling and the upper edge of the measuring containers shall be the maximum specified by the manufacturer. The measuring containers shall be positioned centrally, beneath the single nozzle and beneath the multiple nozzles.

The nozzles shall be discharged both at the minimum and maximum flow rate specified by the manufacturer and the minimum and maximum installation heights specified by the manufacturer.

The water shall be collected for at least 10 minutes to assist in characterizing nozzle performance.

8.11.2 Water Droplet Size (See 7.4.3)

The mean water droplet diameters, velocities, droplet size distribution, number density and volume flux shall be determined at both the minimum and maximum flow rates specified by the manufacturer. Once the data is gathered, the method of the "Standard Practice for Determining Data Criteria and Processing for Liquid Drop Size Analysis" (ASTM E799-92) will be used to determine the appropriate sample size, class size widths, characteristic drop sizes and measured dispersion of the drop size distribution. This data shall be taken at various points within the spray distribution.

8.12 Corrosion Tests

8.12.1 Stress Corrosion Test for Brass Nozzle Parts (See 7.11.1)

Five nozzles shall be subjected to the following aqueous ammonia test.

The samples are degreased and exposed for 10 days to a moist ammonia-air mixture in a glass container of volume 0.02 ± 0.01 m^3.

An aqueous ammonia solution, having a density of 0.94 g/cm^3, shall be maintained in the bottom of the container, approximately 40 mm below the bottom of the samples. A volume of aqueous ammonia solution corresponding to 0.01 ml per cubic centimeter of the volume of the container will give approximately the following atmospheric concentrations: 35% ammonia, 5% water vapor, and 60% air. The inlet of each sample shall be sealed with a nonreactive cap, e.g., plastic.

The moist ammonia-air mixture shall be maintained as closely as possible at atmospheric pressure, with the temperature maintained at 34 ± 2°C. Provision shall be made for venting the chamber via a capillary tube to avoid the build-up of pressure. Specimens shall be shielded from condensate drippage.

After exposure, rinse and dry the nozzles, and conduct a detailed examination. If a crack, delamination or failure of any operating part is observed, the nozzle(s) shall be subjected to a leak resistance test at the rated pressure for 1 minute and to the functional test at the minimum flowing pressure (see 7.1.5).

Nozzles showing cracking, delamination or failure of any non-operating part shall not show evidence of separation of permanently attached parts when subjected to flowing water at the rated pressure for 30 minutes.

8.12.2 Stress-Corrosion Cracking of Stainless Nozzle Parts (See 7.11.1)

8.12.2.1 Five samples are to be degreased prior to being exposed to the magnesium chloride solution.

8.12.2.2 Parts used in nozzles are to be placed in a 500-milliliter flask that is fitted with a thermometer and a wet condenser approximately 760 mm long. The flask is to be filled approximately one-half full with a 42 percent by weight magnesium chloride solution, placed on a thermostatically-controlled electrically heated mantel, and maintained at a boiling temperature of

150 ± 1°C. The parts are to be unassembled, that is, not contained in a nozzle assembly. The exposure is to last for 500 hours.

8.12.2.3 After the exposure period, the test samples are to be removed from the boiling magnesium chloride solution and rinsed in de-ionized water.

8.12.2.4 The test samples are then to be examined using a microscope having a magnification of 25X for any cracking, delamination, or other degradation as a result of the test exposure. Test samples exhibiting degradation are to be tested as described in 8.12.5.5 or 8.12.5.6, as applicable. Test samples not exhibiting degradation are considered acceptable without further test.

8.12.2.5 Operating parts exhibiting degradation are to be further tested as follows:

> Five new sets of parts are to be assembled in nozzle frames made of materials that do not alter the corrosive effects of the magnesium chloride solution on the stainless steel parts. These test samples are to be degreased and subjected to the magnesium chloride solution exposure specified in paragraph 8.12.5.2. Following the exposure, the test samples shall withstand, without leakage, a hydrostatic test pressure equal to the rated pressure for 1 minute, subjected to the functional test at the minimum flowing pressure in accordance with 8.5.1.

8.12.2.6 Nonoperating parts exhibiting degradation are to be further tested as follows:

> Five new sets of parts are to be assembled in nozzle frames made of materials that do not alter the corrosive effects of the magnesium chloride solution on the stainless steel parts. These test samples are to be degreased and subjected to the magnesium chloride solution exposure specified in paragraph 8.12.5.1. Following the exposure, the test samples shall withstand a flowing pressure of the rated pressure for 30 minutes without separation of permanently attached parts.

8.12.3 Sulfur Dioxide Corrosion Test (See 7.11.2)

Ten nozzles shall be subjected to the following sulfur dioxide corrosion test:

> The test equipment shall consist of a 5 liter vessel (instead of a 5 liter vessel, other volumes up to 15 liter may be used in which case the quantities of chemicals given below shall be increased in proportion) made of heat-resistant glass, with a corrosion-resistant lid of such a shape as to prevent condensate dripping on the nozzles. The vessel shall be electrically heated through the base, and provided with a cooling coil around the side walls. A temperature sensor placed centrally 160 mm ± 20 mm above the bottom of the vessel shall regulate the heating so that the temperature inside the glass vessel is 45°C ± 3°C. During the test, water shall flow through the cooling coil at a sufficient rate to keep the temperature of the discharge water below 30°C. This combination of heating and cooling should encourage condensation on the surfaces of the nozzles.

The nozzles to be tested shall be suspended in their normal mounting position under the lid inside the vessel, and subjected to a corrosive sulfur dioxide atmosphere for 16 days. The corrosive atmosphere shall be obtained by introducing a solution made up by dissolving 20 g of sodium thiosulfate ($Na_2S_2O_3H_2O$) crystals in 500 ml of water.

The test shall last one period of 8 days. For at least 6 days of each 8 day period, 20 ml of dilute sulfuric acid consisting of 156 ml of normal H_2SO_4 (0.5 mol/liter) diluted with 844 ml of water shall be added at a constant rate. After 8 days, the nozzles shall be removed from the vessel, and the vessel emptied and cleaned.

The nozzles shall be removed from the container and allowed to dry for 4 to 7 days at a temperature not exceeding 35°C with a relative humidity not greater than 70%.

After the drying period, five nozzles shall be functionally tested at the minimum flowing pressure in accordance with 8.5.1 and five nozzles shall be subjected to the dynamic heating.

8.12.4 Salt Spray Corrosion Test (See 7.11.3)

8.12.4.1 Nozzles Intended for Normal Atmospheres

Ten nozzles shall be exposed to a salt spray within a fog chamber. During the corrosive exposure, the inlet thread orifice is to be sealed by a plastic cap after the nozzles have been filled with deionized water. The salt solution shall be a 20% by mass sodium chloride solution in distilled water. The pH hall be between 6.5 and 7.2 and the density between 1.126 g/ml and 1.157 g/ml when atomized at 35°C. Suitable means of controlling the atmosphere in the chamber shall be provided. The specimens shall be supported in their normal operating position and exposed to the salt spray (fog) in a chamber having a volume of at least 0.43 m^3 in which the exposure zone shall be maintained at a temperature of 35 ± 2°C. The temperature shall be recorded at least once per day, at least 7 hours apart (except weekends and holidays when the chamber normally would not be opened). Salt solution shall be supplied from a recirculating reservoir through air-aspirating nozzles, at a pressure between 0.7 bar (0.07 MPa) and 1.7 bar (0.17MPa). Salt solution runoff from exposed samples shall be collected and shall not return to the reservoir for recirculation.

Fog shall be collected from at least two points in the exposure zone to determine the rate of application and salt concentration. The fog shall be such that for each 80 cm^2 of collection area, 1 ml to 2 ml of solution shall be collected per hour over a 16 hour period and the salt concentration shall be 20 ± 1% by mass.

The nozzles shall withstand exposure to the salt spray for a period of 10 days. After this period, the nozzles shall be removed from the fog chamber and allowed to dry for 4 to 7 days at a temperature not exceeding 20 to 25°C in an atmosphere having a relative humidity not greater than 70%. Following the drying period, five nozzles shall be submitted to the functional test at the minimum flowing pressure in accordance with 8.5.1 and five nozzles shall be subjected to the dynamic heating test in accordance with 7.14.2.

8.12.4.2 Nozzles Intended for Corrosive Atmospheres

Five nozzles shall be subjected to the tests specified in 8.12.3.1 except that the duration of the salt spray exposure shall be extended from 10 days to 30 days.

8.12.5 Moist Air Exposure Test (See 7.11.4)

Ten nozzles shall be exposed to a high temperature-humidity atmosphere consisting of a relative humidity of 98% ± 2% and a temperature of 95°C ± 4°C. The nozzles are to be installed on a pipe manifold containing deionized water. The entire manifold is to be placed in the high temperature humidity enclosure for 90 days. After this period, the nozzles shall be removed from the temperature-humidity enclosure and allowed to dry for 4-7 days at a temperature not exceeding 25 ± 5°C in an atmosphere having a relative humidity of not greater than 70%. Following the drying period, five nozzles shall be functionally tested at the minimum flowing pressure in accordance with 8.5.1 and five nozzles shall be subjected to the dynamic heating test in accordance with 7.14.2.

> **NOTE:** At the manufacturer's option, additional samples may be furnished for this test to provide early evidence of failure. The additional samples may be removed from the test chamber at 30 day intervals for testing.

8.13 Nozzle Coatings Tests

8.13.1 Evaporation Test (See 7.12.1)

A 50 cm^3 sample of wax or bitumen shall be placed in a metal or glass cylindrical container, having a flat bottom, an internal diameter of 55 mm and an internal height of 35 mm. The container, without lid, shall be placed in an automatically controlled electric, constant ambient temperature oven with air circulation. The temperature in the oven shall be controlled at 16°C below the nominal release temperature of the nozzle, but at not less than 50°C. The sample shall be weighed before and after 90 days' exposure to determine any loss of volatile matter; the sample shall meet the requirements of 7.12.1.

8.13.2 Low-Temperature Test (See 7.12.2)

Five nozzles, coated by normal production methods, whether with wax, bitumen or a metallic coating, shall be subjected to a temperature of -10°C for a period of 24 hours. On removal from the low-temperature cabinet, the nozzles shall be exposed to normal ambient temperature for at least 30 minutes before examination of the coating to the requirements of 7.1.12.2.

8.14 Heat-Resistance Test (See 7.15)

One nozzle body shall be heated in an oven at 800°C for a period of 15 minutes with the nozzle in its normal installed position. The nozzle body shall then be removed, holding it by the threaded inlet, and shall be promptly immersed in a water bath at a temperature of approximately 15°C. It shall meet the requirements of 7.15.

8.15 Water-Hammer Test (See 7.13)

Five nozzles shall be connected, in their normal operating position, to the test equipment. After purging the air from the nozzles and the test equipment, 3000 cycles of pressure varying from 4 ± 2 bar ((0.4 ± 0.2) MPa) to twice the rated pressure shall be generated. The pressure shall be raised from 4 bar to twice the rated pressure at a rate of 60 ± 10 bar/s. At least 30 cycles of pressure per minute shall be generated. The pressure shall be measured with an electrical pressure transducer.

8.16 Vibration Test (See 7.16)

8.16.1 Five nozzles shall be fixed vertically to a vibration table. They shall be subjected at room temperature to sinusoidal vibrations. The direction of vibration shall be along the axis of the connecting thread.

8.16.2 The nozzles shall be vibrated continuously from 5 Hz to 40 Hz at a maximum rate of 5 minutes/octave and an amplitude of 1 mm (1/2 peak-to-peak value). If one or more resonant points are detected, the nozzles after coming to 40 Hz, shall be vibrated at each of these resonant frequencies for 120 hours/number of resonances. If no resonances are detected, the vibration from 5 Hz to 40 Hz shall be continued for 120 hours.

8.16.3 The nozzle shall then be subjected to the leakage test in accordance with 7.8.1 and the functional test in accordance with 7.5.1 at the minimum operating pressure.

8.17 Impact Test (See 7.17)

Five nozzles shall be tested by dropping a mass onto the nozzle along the axial center line of waterway. The kinetic energy of the dropped mass at the point of impact shall be equivalent to the mass equal to that of the test nozzle dropped from a height of 1 m (see Figure 2). The mass is to be prevented from impacting more than once upon each sample.

Following the test, a visual examination of each nozzle shall show no fracture, deformation, or other deficiency. If none is detected, the nozzles shall meet the leak resistance test, described in 8.4.1. Following the leakage test, each sample shall meet the functional test requirement of 8.5.1 at a pressure equal to the minimum flowing pressure.

8.18 Machinery Space Fire Test Method (See 7.18.1)

8.18.1 Test Apparatus

A. 3.2 m by 5.2 m by 0.5 m high steel floor plate assembly with enclosed sides; two 1 m by 2 m by 0.1 m high and one 2 m by 2 m by 0.1 m high steel trays are to be positioned under the floor plate assembly as shown in Figure 3, and

B. An engine mock-up 1 m by 3 m by 2 m high constructed of nominal 5 mm thick sheet steel; a 1 m x 3 mm by 0.1 m high steel tray is to be positioned on top of the engine mock-up; the engine mock-up is to be fitted with 2 steel tubes 0.3 m in diameter, 3 m in length. See Figure 3.

8.18.2 Test Room

8.18.2.1 Class I Engine Room

The fire tests shall be conducted in test room having a minimum floor area of 80 m^2 with no dimension less than 8 m, a ceiling height of 5 m and ventilation through a minimum of 4 m^2 door opening.

8.18.2.2 Class II Engine Room

The fire tests shall be conducted in a test room having a minimum floor area of 300 m^2 and a volume of 3000 m^3. A ceiling is to be positioned at a height between 5 and 10 m above the floor. The height of the ceiling will be the maximum recommended by the manufacturers.

> **NOTE:** A test room having a smaller floor area and volume may be used if it can be assured that the fire is not affected by oxygen depletion.

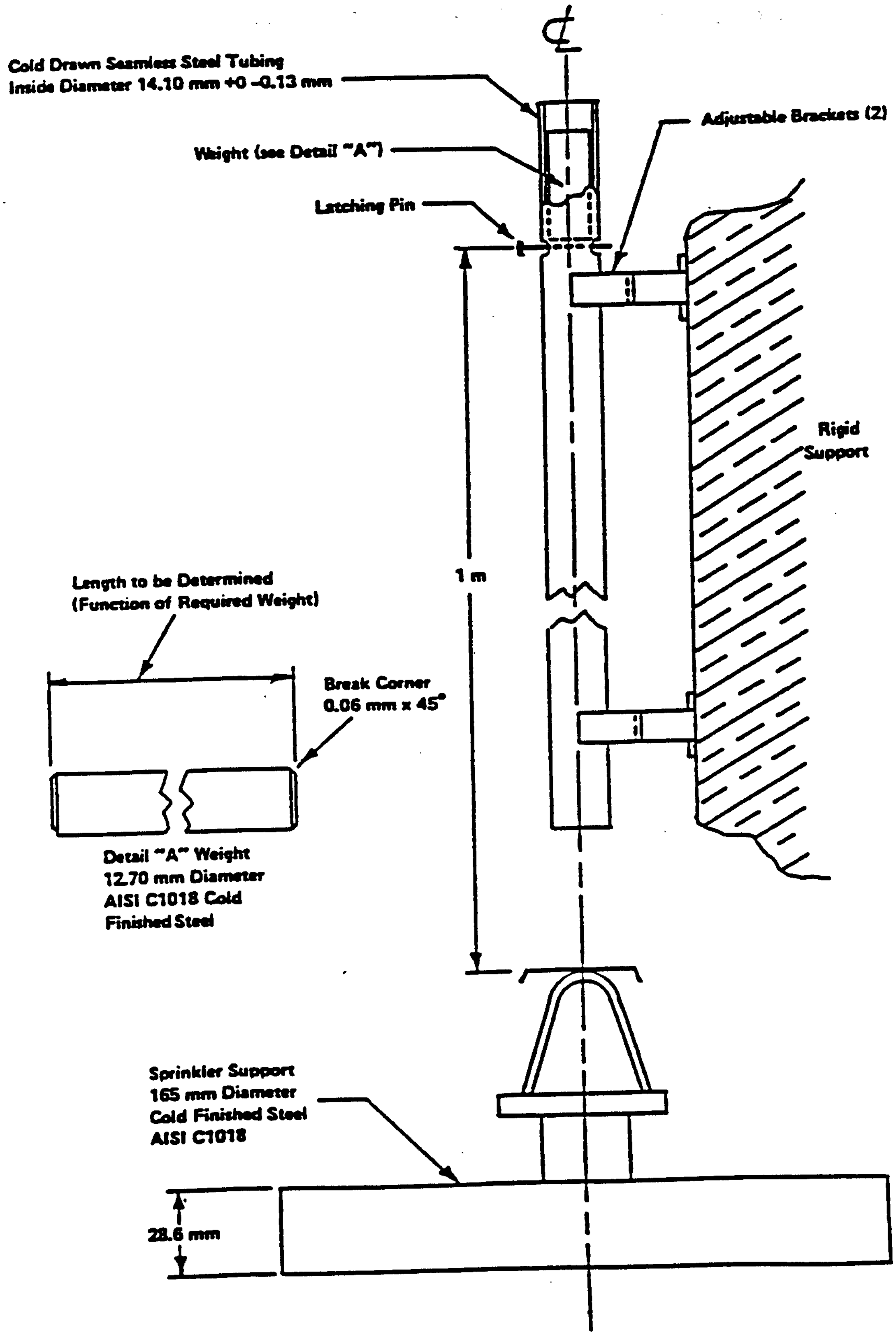


Figure 2. Impact Test Apparatus

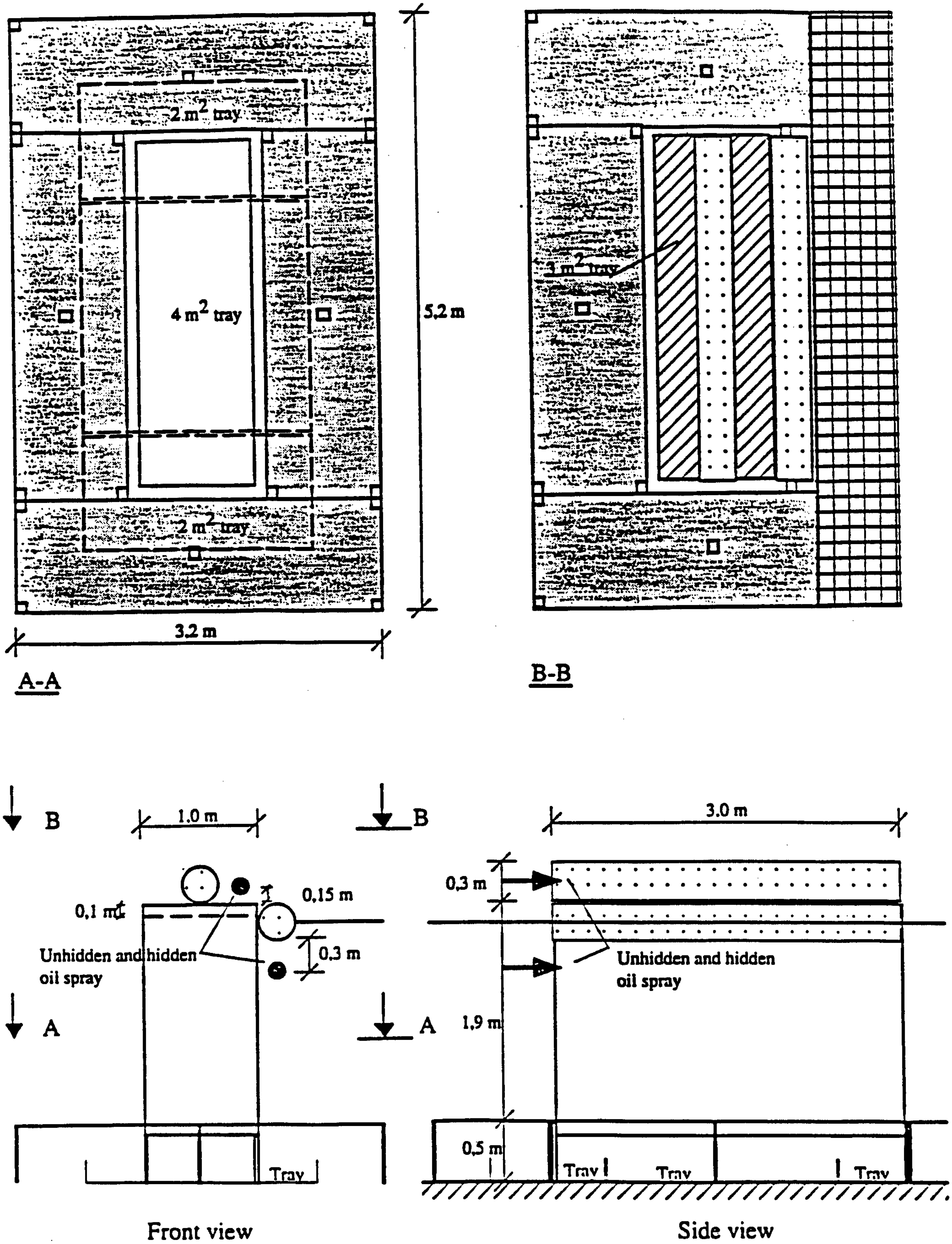


Figure 3. Engine Mock–Up Details

8.18.2.2 Class III Engine Room

The fire tests shall be conducted in a test room having a minimum floor area of 300 m^2 and a volume greater than 3000 m^3. The ceiling height shall be greater than 10 m.

> NOTE: A test room having a smaller floor area and volume may be used if it can be assured that the fire is not affected by oxygen depletion.

8.18.3 Fire Tests

8.18.3.1 High Risk Areas

A series of fire tests are to be conducted as described in Table 9. The oil spray nozzles, discharge pressures, flow rates and oil temperature are described in Table 10. For fires in the test trays, the fuel depth shall be 50 mm.

Table 9. Fire Tests for High Risk Areas

Test No.	Fire Scenario	Test Fuel
1	Low pressure spray on top of engine mock-up under 1 nozzle	Commercial fuel oil or light diesel oil
2	Low pressure spray on top of engine mock-up centered between 2 nozzles	Commercial fuel oil or light diesel oil
3	Low pressure spray on top of engine mock-up centered between 4 nozzles	Commercial fuel oil or light diesel oil
4	Low pressure spray on top of engine mock-up centered with nozzle angled upward at a 45° angle to strike a 12-15 mm rod 1 meter away	Commercial fuel oil or light diesel oil
5	Low pressure concealed spray fire on side of engine mock-up with oil spray nozzle centered between 2 nozzles	Commercial fuel oil or light diesel oil
6	Low pressure concealed spray fire on side of engine mock-up with oil nozzle across from 1 nozzle	Commercial fuel oil or light diesel oil
7	Combination of worst spray fire from Tests 1-6 and fires in trays under and on top of the engine mock-up	Commercial fuel oil or light diesel oil
8	High pressure spray fire on top of engine mock-up	Commercial fuel oil or light diesel oil
9	Low pressure concealed spray fire on side of engine mock-up	SAE 10W30 mineral based lubrication oil
10	Fires in grays under and on top of the engine mock-up	SAE 10W30 mineral based lubrication oil

Table 10. Oil Spray Fire Test Parameters

	Category A Engine Room		
	Class 1	**Class 2 and 3**	**Class 1-3**
Fire Type	**Low Pressure**	**Low Pressure**	**High Pressure**
Spray Nozzle	Wide spray angle (120 to 125°) full cone type	Wide spray angle (120 to 125°) full cone type	Standard angle (at 6 Bar) full cone type
Nominal oil pressure	8 Bar	10 Bar	150 Bar
Oil Flow	0.16 ± 0.01 kg/s	0 ± 0.01 kg/s	0.050 ± 0.002 kg/s
Oil Temperature	20 ± 5°C	20 ± 5°C	20 ± 5°C

8.18.3.2 Low Risk Areas

Conduct these fire tests in a test room hoving a minimun floor area of 80 m^2, a ceiling height of 5 m and a minimum 4 m^2 door opening. A 1 m by 2 m by 0.1 m high steel test tray is to be filled to a depth of 50 mm with light diesel oil or equivalent.

8.18.3.3 Test Fuels

Fire tests 1-8 described in Table 9 are to be conducted using commercial fuel oil or a light diesel oil. Fire tests 9 and 10 are to be conducted using a SAE 10W30 mineral based lubrication oil.

8.18.4 Extinguishing System

8.18.4.1 The extinguishing system shall be installed to protect the high and low risk hazards in accordance with the manufacturer's installation and design criteria.

8.18.4.2 Fire tests shall be conducted with the nozzles positioned at the minimum and maximum distances from the test apparatus, at the maximum spacing between nozzles and at the nominal extinguishing pressure(s) recommended by the manufacturer.

8.18.5 Test Procedure

8.18.5.1 The test tray(s) shall be filled with 50 mm of test fuel without a water base.

8.18.5.2 For oil spray fire tests, the oil flow and pressure shall be measured before each test. The pressure shall be measured during each test.

8.18.5.3 After ignition of the fuel in the test trays, a 2 minute preburn is permitted before the oil spray (if required) is ignited and the extinguishing system activated.

8.18.5.4 The pressure in the extinguishing system piping to each nozzle shall be measured at intervals not exceeding 5 seconds during each test.

8.18.5.5 After the preburn, the extinguishing system shall be discharged for 50 percent of the discharge time recommended by the manufacturer or 15 minutes, whichever is less. At the end of discharge, there shall be complete extinguishment and no reignition. The oil spray, if used, shall be shut-off 15 seconds after the end of agent discharge.

8.18.6 Test Observations

The following observations shall be recorded:

A. Start of ignition procedures
B. Ignition
C. Time of extinguishing system activation
D. Time of fire extinguishment
E. Time when extinguishing system was shut-off
F. Time of reignition, if any
G. Time when oil spray was shut-off
H. Damage to any extinguishing system components, and
I. Presence of fuel in all test trays

8.19 Accommodation Space Fire Tests (See 7.18.2)

8.19.1 12 m^2 Cabin and Corridor

8.19.1.1 Test Arrangement

The fire tests shall be conducted in a 3 by 4 m by 2.4 m high cabin centrally connected to a 1 m by 12 m long corridor 2.4 m high. The walls of the cabin are to be constructed from an inner and outer layer of 12 m thick wall board with a 45 m thick mineral wool liner. The walls and ceiling of the corridor and ceiling of the passenger cabin shall be constructed of 12 m thick wall board. The cabin should be provided with a window in the wall opposite the corridor for observation purposes during the fire tests. See Figure 4.

8.19.1.2 One end of the corridor is to be closed off and the other end positioned under a calorimeter to measure rate of heat release versus time.

8.19.1.3 Fire Source

Two pullman type bunk beds having an upper and lower birth are to be installed along opposite walls of the cabin. See Figure 4. Each bunk bed is to be fitted with 2000 mm by 800 mm by 100 mm polyester mattresses having a cotton fabric cover. Pillows measuring 500 mm by 800 mm by 100 mm are to be made from the same materials as the mattress. A third mattress shall form a backrest for the lower bunk bed. See Figure 5.

8.19.1.4 Thermocouples

To record temperatures, during each fire test, thermocouples with a nominal thickness of 0.25 mm shall be located adjacent to the water mist nozzle(s) in the cabin and at distances of 20, 50, 80, 100, 120, and 150 cm below the ceiling in the center of the room. Care shall be taken to position the thermocouples so that they are not directly impinged by the spray from the nozzle. Two sets of thermocouples shall be located in its corridor at distances of 10, 20, 30, 40, 50, 80, and 100 cm below the ceiling.

The thermocouples are to be positioned in the center of the corridor directly opposite the cabin doorway and between 2 water mist nozzles in the corridor. See Figure 6.

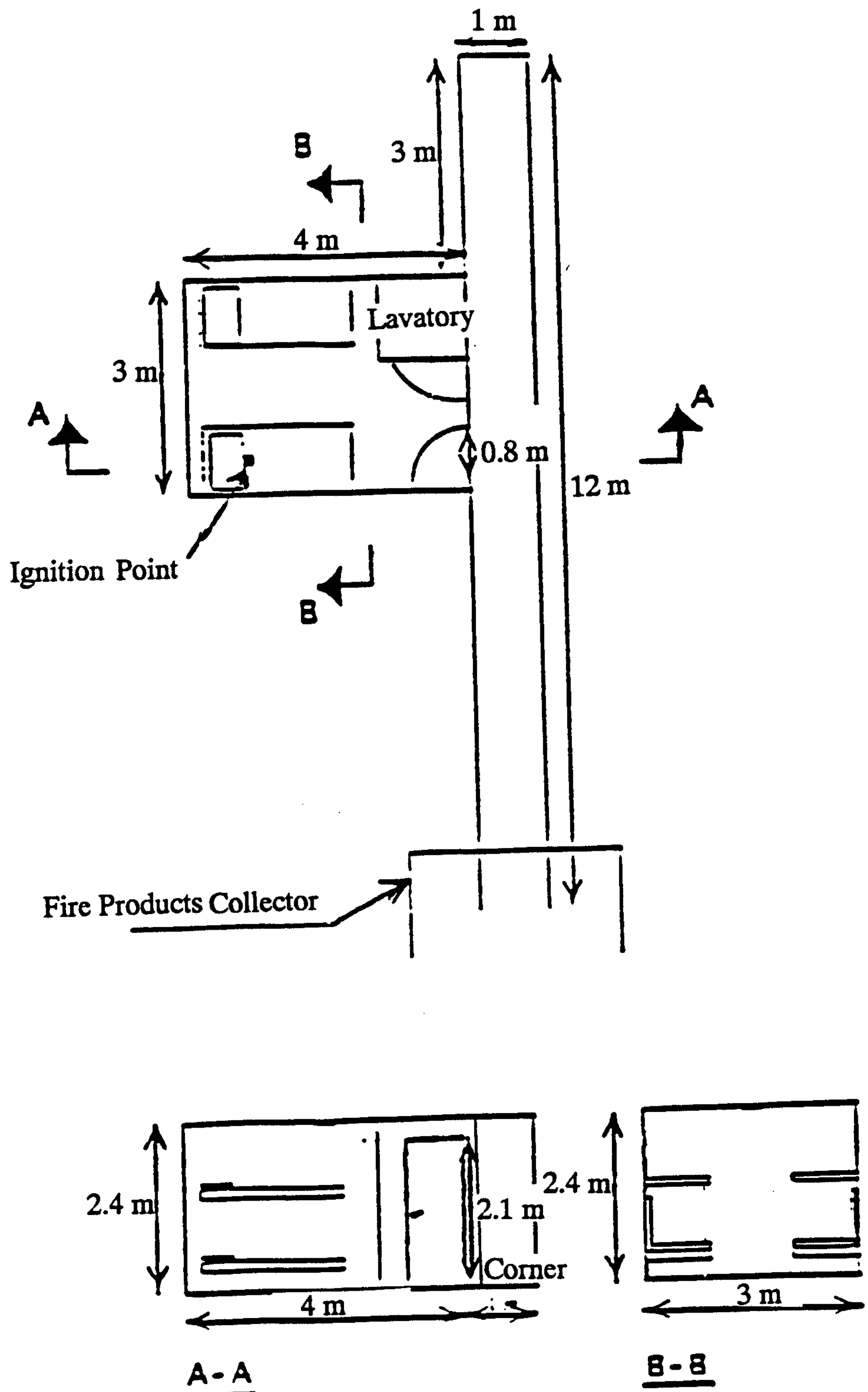


Figure 4. 12 m^2 Cabin and 12 m Corridor Details

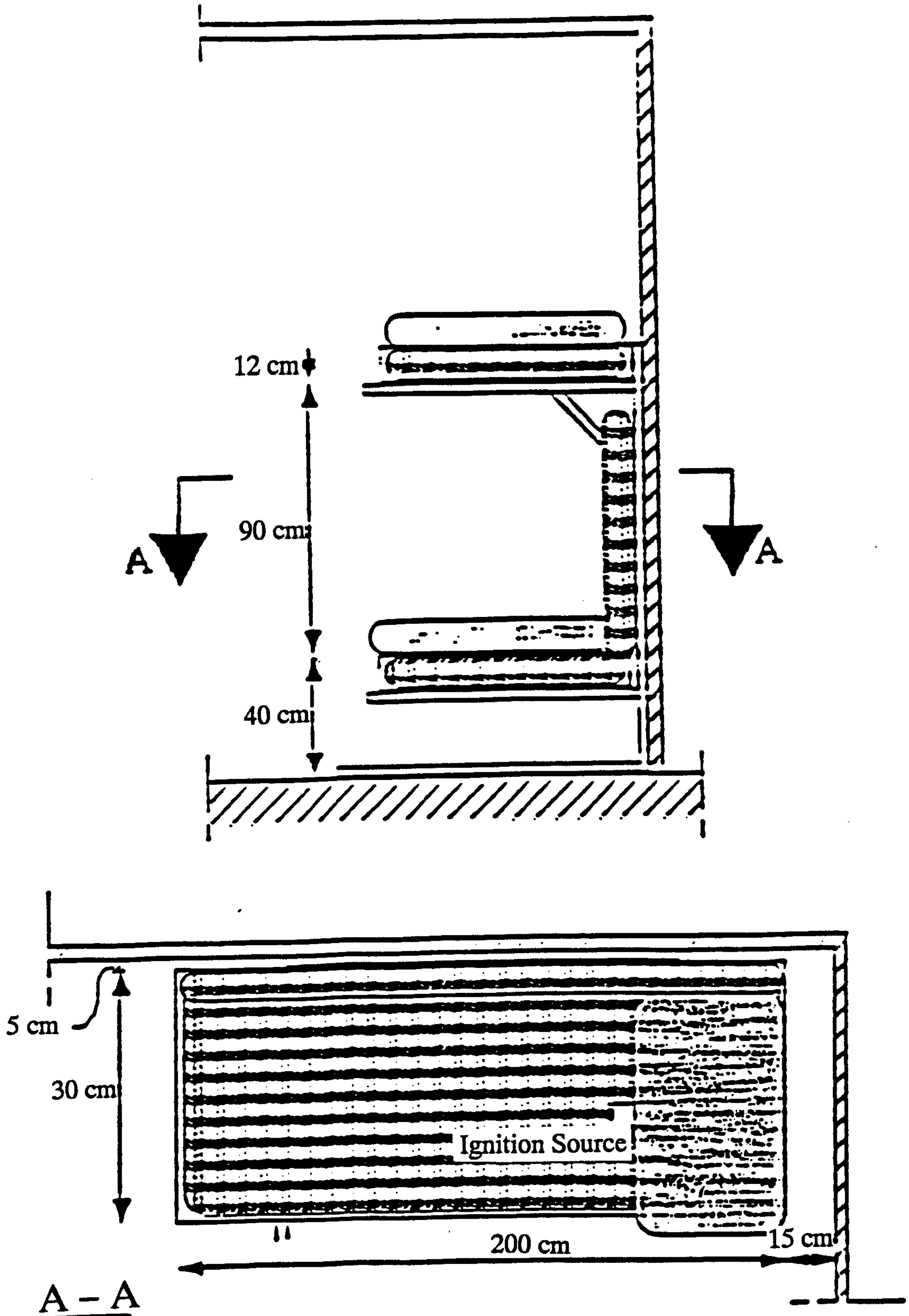


Figure 5. Bunk Bed Arrangement

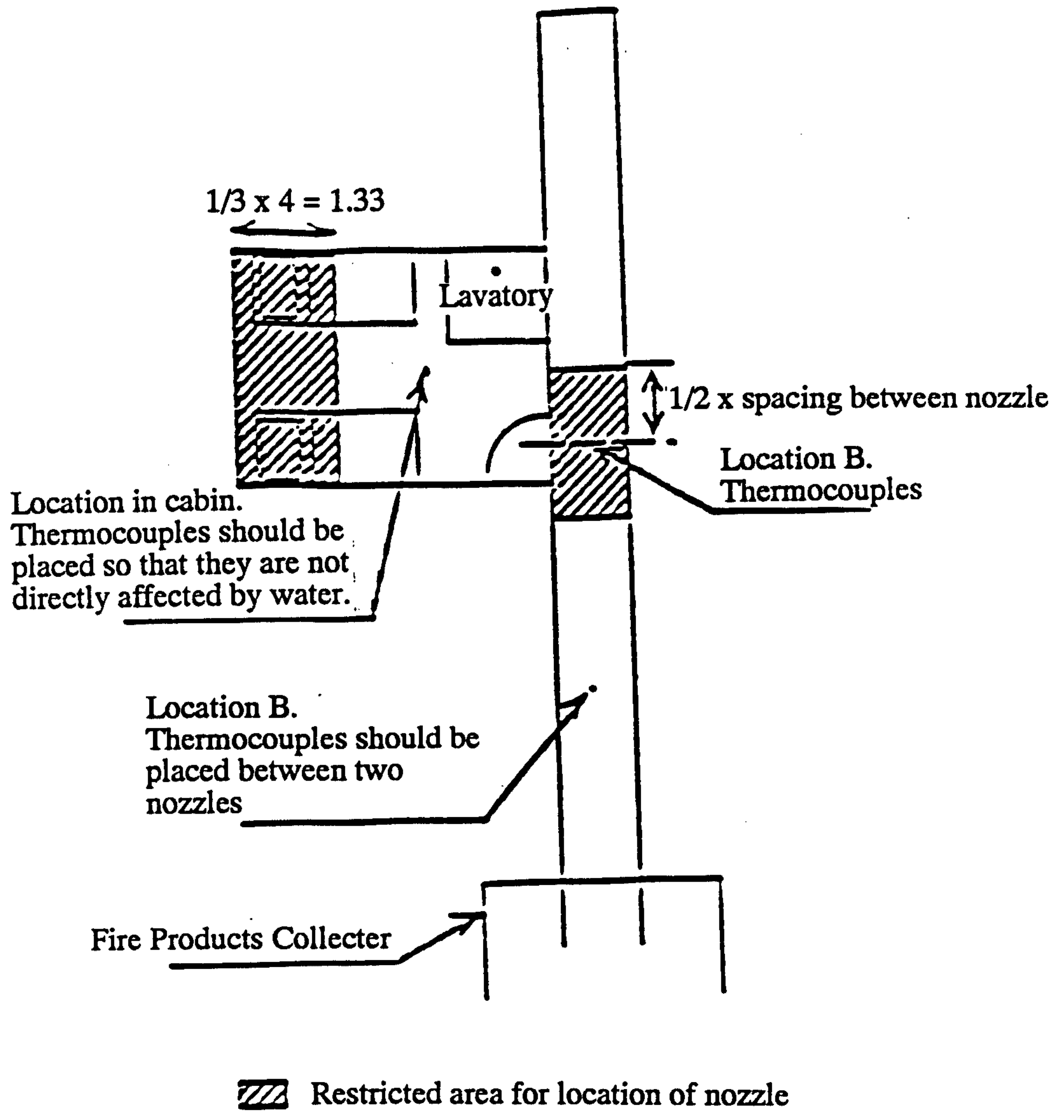


Figure 6. Location of Thermocouples in the Cabin/Corridor and Areas Restricted for Location of Nozzles (dimensions in meters)

8.19.1.5 Placement of Water Mist Nozzles

The water mist nozzles shall be installed to protect the cabin and corridor in accordance with the Manufacturer's Design and Installation Instructions subject to the following:

A. If only one water mist nozzle is installed in the cabin, it shall not be placed in the shaded area in Figure 6, and

B. Corridor water mist nozzles shall not be placed nearer to the centerline of the cabin doorway than one half the maximum spacing recommended by the manufacturer.

8.19.1.6. Required Fire Tests

8.19.1.6.1 The following series of 4 cabin fire tests shall be conducted. All fires shall be ignited using a 75 mm cube of insulating fiberboard soaked in 115 ml of heptane and wrapped in a plastic bag:

1. Automatic activation of the water mist nozzles installed in the cabin and corridor, fire arranged in one lower bunk bed,
2. Automatic activation of the water mist nozzles installed in the cabin and corridor, fire arranged in one upper bunk bed,
3. Automatic activation of the water mist nozzles installed in the cabin and corridor, fire arranged by spreading 1 liter of white spirits evenly over one lower bunk bed and backrest, and
4. Automatic activation of the water mist nozzles in the corridor with the water mist nozzle(s) in the cabin disabled, fire arranged in one lower bunk bed.

8.19.1.6.2 A corridor fire test is to be conducted using 8 mattress pieces measuring 405 mm by 400 mm by 100 mm placed on a steel test stand 250 mm high positioned between 2 water mist nozzles (see Figure 7). For the corridor fire test, the walls and ceiling are to be fitted with combustible panel or ceiling tiles over the wall board. The mattress stand shall be positioned 50 mm from one wall. The mattress pieces are ignited using a 75 mm cube of insulated fiberboard soaked in 115 ml of heptane, and placed in a plastic bag centered under the test stand.

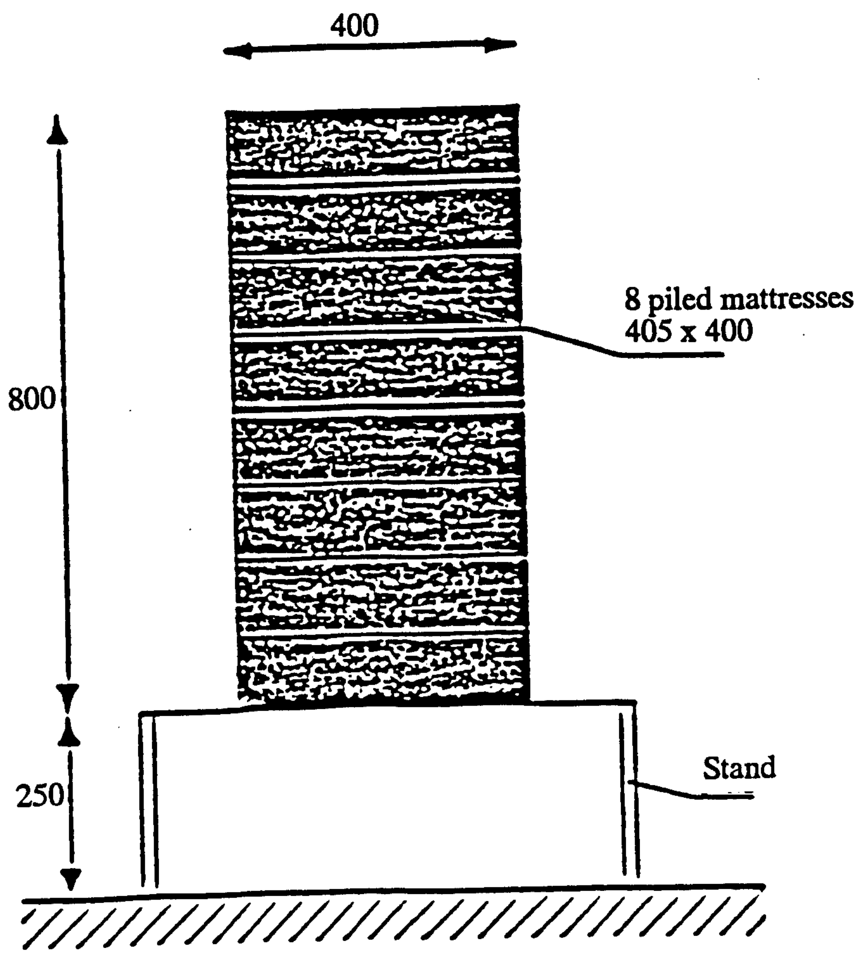


Figure 7. Corridor Fire Fuel Package (dimensions in millimeters)

8.19.1.7 Test Observations

The following observations shall be made during each fire test:

A. Ignition
B. Water mist nozzle(s) activation
C. Fire suppression
D. Time when water flow is shut-off
E. Presence of unburnt fuel
F. Time of reignition, if any
G. Rate of heat release at intervals not exceeding 5 seconds
H. Temperature recordings
I. Flow rate and flowing pressure at each nozzle, and
J. Total number of operating nozzles.

8.19.2 Passenger Cabins Greater than 12 m^2 (See 7.18.2.1)

8.19.2.1 Test Arrangement

These fire tests are to be conducted in a 2.4 m high room having a floor area of at least 24 m^2. The room is to be fitted with doorway openings in two opposite corners of the room. Each opening is to be 0.8 m wide and 2.2 m high, which provides for a 200 mm lintel above the openings.

8.19.2.2 The test room ceiling is to be covered with cellulosic acoustical panels that are attached to furring strips. The acoustical panels are to consist of nominal 0.6 m by 1.2 m, be 12.7 mm thick, and have a maximum flame spread index of 25 when tested in accordance with the Test for Surface Burning Characteristics of Building Materials, ANSI/UL 7223.

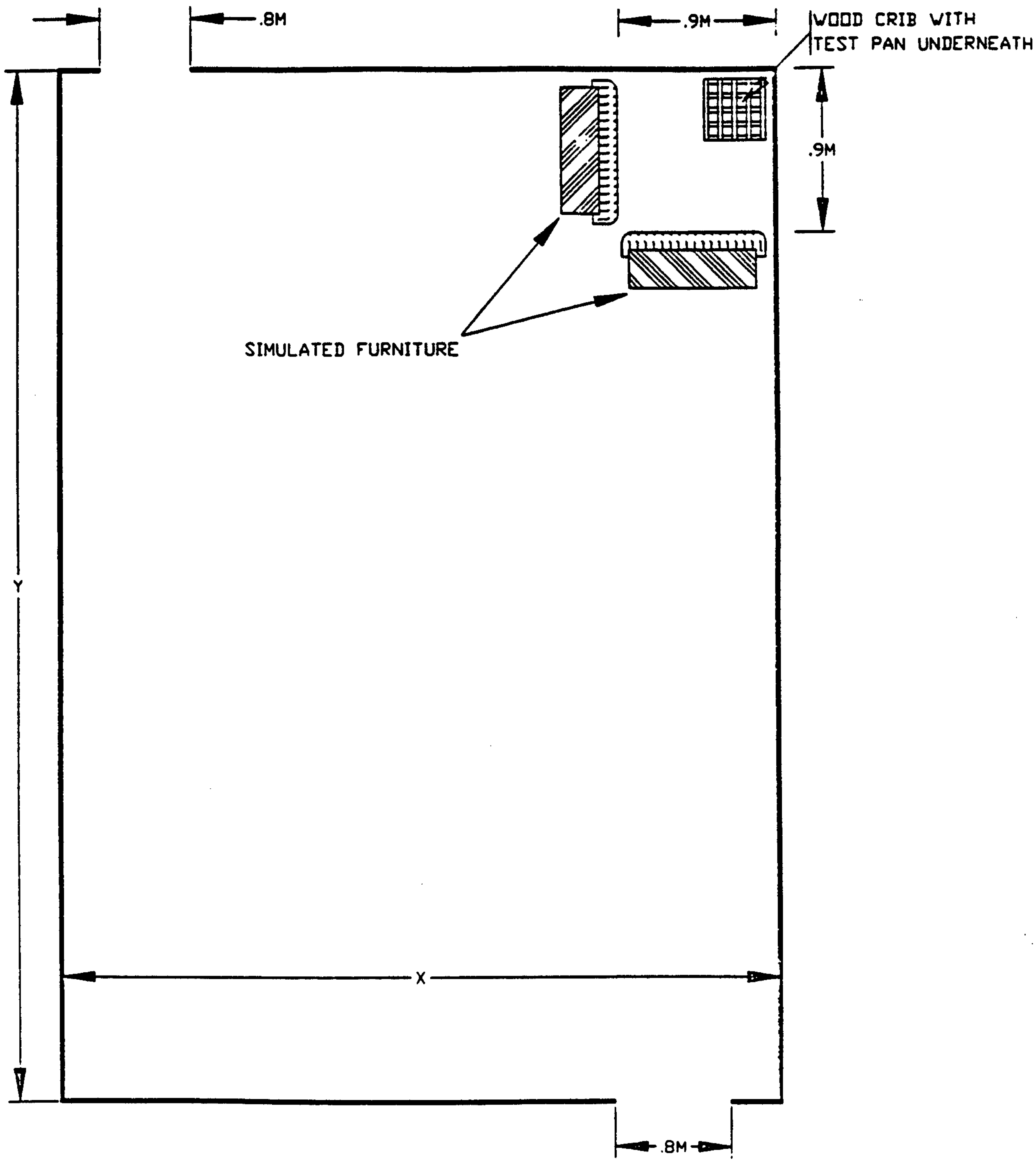
8.19.2.3 Decorative plywood panels measuring 1.2 m by 2.4 m are to be placed on two of the test room walls extending out from a common corner. Two panels are to be placed on each wall. The panels are to be approximately 3 mm thick and have a flame spread index of 200 when tested in accordance with the Standard for Test for Surface Burning Characteristics of Building Materials, ANSI/UL 723. They are to be placed on the walls by being attached to 12.7 mm thick wood furing strips. See Figure 8.

8.19.2.4 Fire Source

The fire source is to consist of a wood crib and simulated source. See Figure 8 for placement of the fire source in the test room.

8.19.2.5 The wood crib is to weigh approximately 6 kg and is to be dimensioned 305 by 305 by 305 mm. The crib is to consist of eight alternate layers of four trade size nominal 38.1 mm by 38.1 mm kiln-dried spruce or fir lumber 305 mm long. The alternate layers of the lumber are to be placed at right angles to the adjacent layers. The individual wood members in each layer are to be evenly spaced along the length of the previous layer of wood members and stapled.

8.19.2.6 After the wood crib is assembled, it is to be conditioned at a temperature of 50 ± 3°C for not less than 16 hours. Following the conditioning, the moisture content of the crib is to be measured at various locations with a probe type moisture meter. The moisture content of the crib shall not exceed 5 percent prior to the fire test. The crib is to be placed on top of a 305 x 305 x 100 mm high steel test tray and positioned 25 mm from each wall. See Figure 9.



XY ≥ 24 Square Meters

Figure 8. 24 m^2 and Larger Cabin Fire Test Arrangement

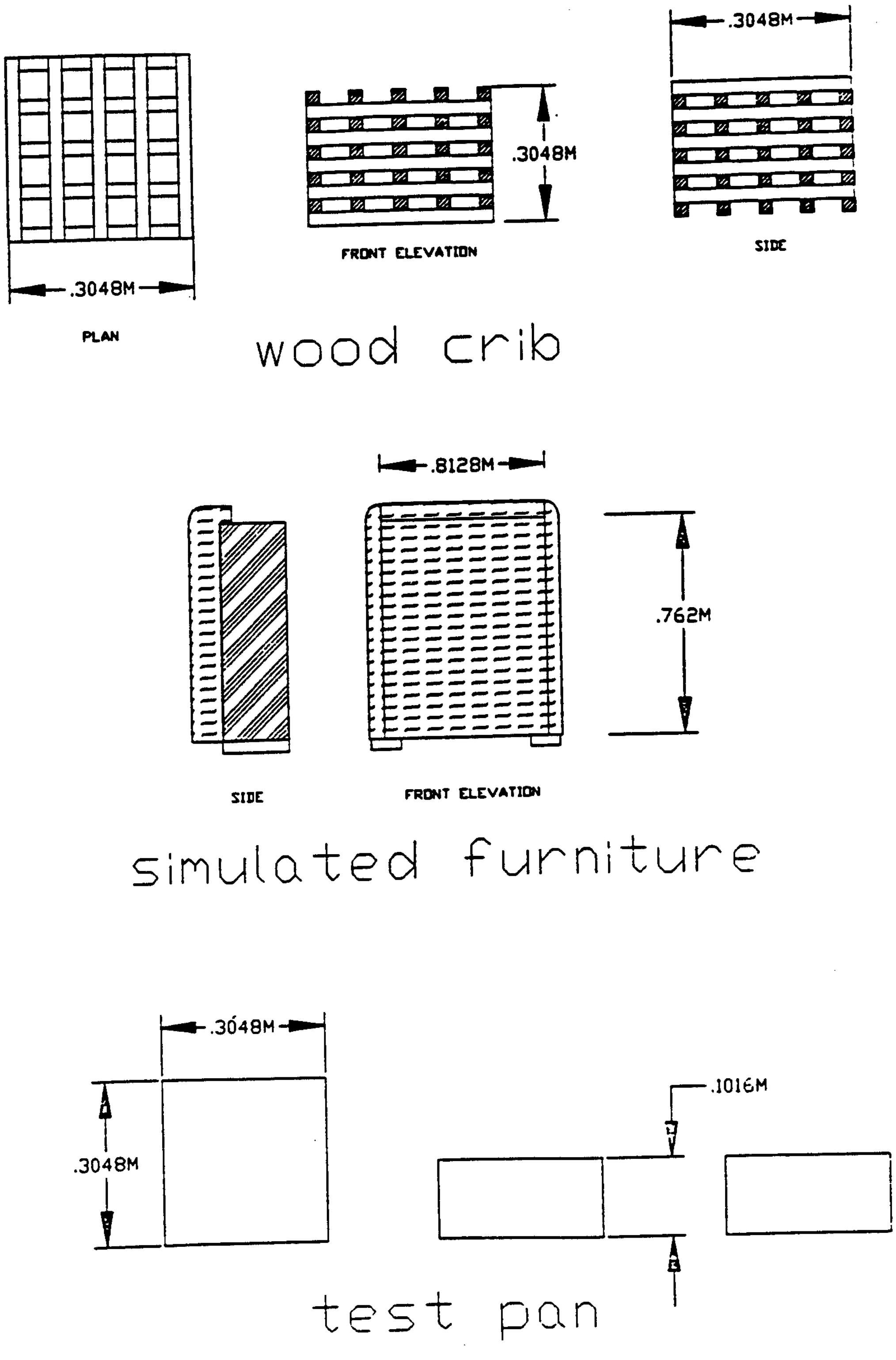


Figure 9. Cabin Fire Test Crib and Simulated Furniture Fuel Package

8.19.2.7 The simulated furniture is to consist of two 76.2 mm thick uncovered polyether foam cushions having a density of 16 to 20 kg/m^3, having a compressive strength of 147 to 160 N, measuring 914 by 1016 mm, each attached to a wood support frame. The wood support frame has a rectangular plywood face measuring approximately 810 mm x 760 mm onto which the foam cushions are applied. The cushions are secured onto plywood panels which extend perpendicular to the face towards the opposite end of the frame by approximately 180 mm. Each cushion is to overlap the top of the wood frame by approximately 150 mm and the sides of the wood frame by approximately 177 mm. See Figure 9.

8.19.2.8 Nozzle Installation

Water mist nozzles are to be installed in the test room for each fire test in accordance with the Manufacturer's Design and Installation Instructions. Nozzles are to be installed with their deflector/spray orifices located 76 mm below the ceiling or as specified in the installation instructions if other than 76 mm.

8.19.2.9 Nozzles are to be positioned with their frame arms parallel and perpendicular to the supply piping, or for nozzles without frame arms, so that the lightest discharge density, as determined in the Water Distribution Test (see 8.11) will be directed toward the fire area.

8.19.2.10 Test Method

The test room is to have a starting ambient temperature of 27°C measured at the thermocouple located 76 mm below the ceiling.

8.19.2.11 The temperatures at each thermocouple location are to be continuously recorded during the test using 0.52 mm^2, No. 20 AWG chromel-alumel thermocouples. The thermocouples are to be shielded from impingement of water from the nozzle discharge.

8.19.2.12 Two-tenths liter of heptane is to be placed on a 5 mm water base in the test tray positioned directly below the wood crib. Approximately 115 gallons of excelsior (wood wool) is to be pulled apart and loosely positioned on the floor adjacent to each section of simulated furniture.

8.19.2.13 The heptane is to be ignited and 40 seconds later the excelsior is also to be ignited.

8.19.2.14 The fire test is to be conducted for 10 minutes after the ignition of the wood crib. The water flow rate to the nozzles is to be the flow rate specified in the Manufacturer's Design and Installation Instructions.

8.20 Public Space Fire Tests

8.20.1 Light Hazard Areas (See 7.18.3.1)

8.20.1.1 Test Room

The fire tests are to be conducted in a test room fitted with a ceiling at least 80 m^2 in area with no dimension less than 8 m. The ceiling shall be at least 2 m away from any walls. The ceiling height shall be set at 2.5 m for 1 set of tests and at the maximum ceiling height specified by the manufacturer for the second test.

8.20.1.2 Fire Source

The fire source is to consist of 4 sofas constructed from 2000 m by 800 mm by 100 mm polyether mattresses filled with a cotton fabric cover. The mattresses shall be arranged as shown in Figure 10 and centered between 2 and 4 nozzles.

A 75 mm cube of insulating fiberboard is to be soaked in 115 ml of heptane and placed in a plastic bag. The bag is then placed in the middle of the bottom mattress of one of the sofas.

8.20.1.3 Temperatures

Temperatures are to be recorded 10 cm below the ceiling directly above the ceiling and adjacent to the nozzles. Thermocouples having a minimum thickness of 0.25 mm shall be used.

8.20.1.4 Nozzle Installation

Water mist nozzles are to be installed below the ceiling at the maximum spacing specified in the Manufacturer's Design and Installation Instructions. For nozzles with frame arms, tests are to be conducted with the frame arms positioned both perpendicular and parallel to the system supply piping.

The water flow and operating pressure is to be monitored during each 10 minute test.

8.20.1.5 Observations

The following observations are to be made during each test:

A. Time of ignition,
B. Activation times of each nozzle,
C. Time when fire is extinguished,
D. Time when water is shut-off,
E. Time of reignition, if any,
F. Percent of damage to each mattress, and
G. Total quantity of water used

8.20.2 Ordinary Hazard Areas (See 7.18.3.2)

8.20.2.1 Test Room

The test room shall be a ventilated draft-free enclosure and shall have a minimum floor area of 144 m^2, with no floor dimension less than 12 m. The ceiling height shall be sufficient to accommodate the assembly as shown in Figure 12. The total air inlet area to the test room shall be not less than 1 m^2. Provisions shall be made, either by venting or by the dimensions of the test room, to evacuate or dissipate smoke.

8.20.2.2 Fuel Source

The test shall be conducted using cribs of sawn lengths of *Pinus Sylvestris* (pine) or *Picea excelsa* (spruce).

Each crib shall contain two lengths of nominal dimensions 100 mm x 150 mm x 2400 mm, 13 lengths of nominal dimensions 100 mm x 100 mm x 1200 mm, and 28 lengths of nominal dimensions 50 mm x 100 mm x 1200 mm. The average moisture content of the wood shall be between 6% and 14%. See Figure 11.

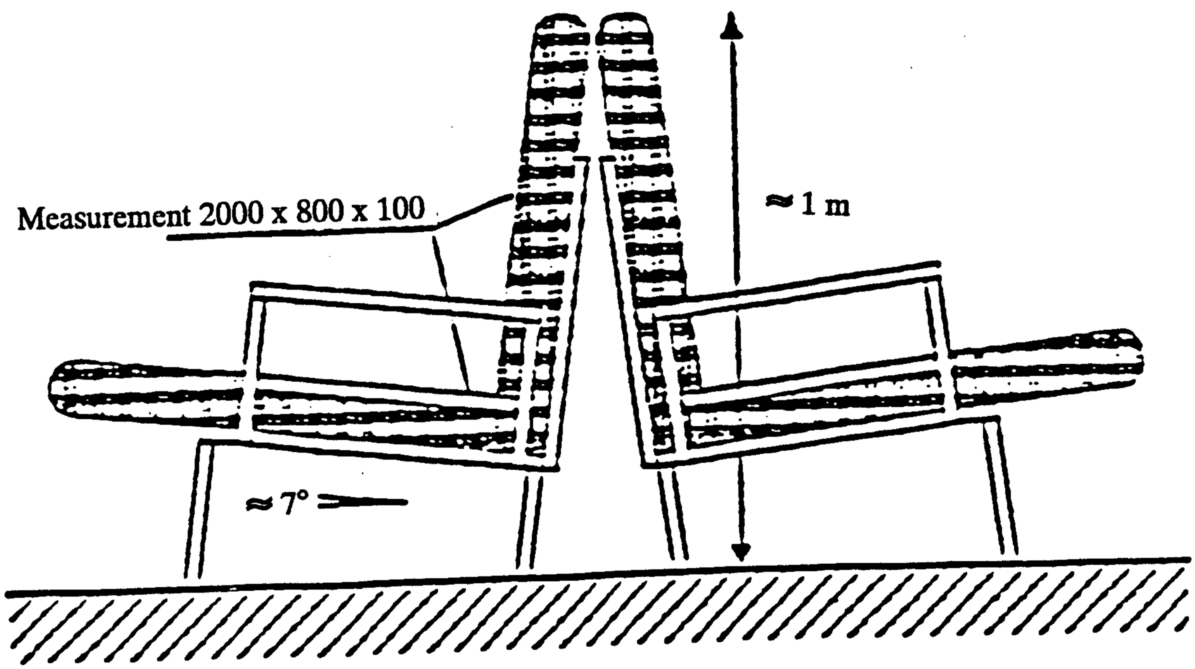


Figure 10. Sofa Arrangement Fuel Package (dimensions in millimeters)

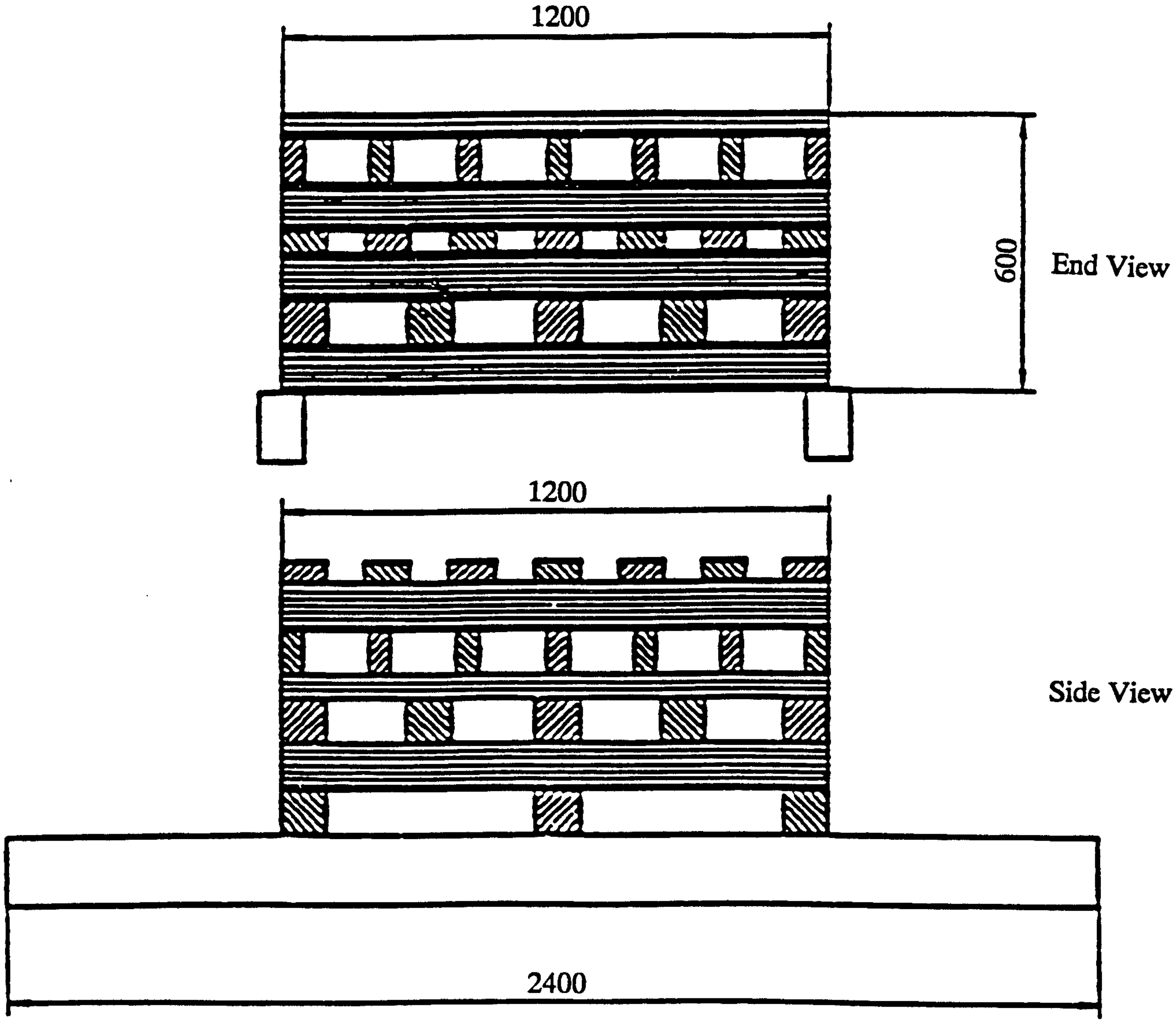


Figure 11. Fire Crib Schematic (dimensions in millimeters)

The timber specified above is to be layered by being evenly spaced from each other, and forming a square crib, 1200 mm by 1200 mm in area, and 600 mm high, supported in turn, by the two 2400 mm long, 100 mm by 150 mm stringers. The total weight of the timber in the crib is to be determined and recorded.

The crib stringers are to be supported by a steel framework of channel iron mounted on adjustable pipe supports. See Figure 12.

A supply of heptane or equivalent fuel, sufficient for 30 minutes, and a nozzle[6] shall be incorporated in the assembly as shown in Figure 12. The spray should form a hollow cone having an angle of approximately 75° when atomizing the fuel at a rate of 0.06 liter/second. To prevent flameout, an igniter shall be located next to the nozzle. This may be a cylindrical container partially filled with heptane.

The steel pan shall be 1800 mm x 2400 mm x 300 mm (depth), constructed of steel plate not less than 5, 4 mm thick. The upper corners shall be reinforced by a continuous steel band. The pan shall be liquid-tight and, prior to the test, shall be filled with water to a depth of 100 mm. The pan shall be provided with means of drainage to maintain the water level at 100 mm.

8.20.2.3 Nozzle Installation

Open nozzles shall be placed under an unobstructed portion of ceiling having a minimum area of 5000 mm x 5000 mm. The nozzles shall be mounted with the maximum distance specified in the Manufacturer's Design and Installation Instructions between the nozzles on each side and arranged to protect an area of approximately 3 x 3 m. The wood crib shall be centered below the nozzles at the minimum and maximum distances specified by the manufacturer below the outlet of the nozzle. Nozzle frame arms, if provided, shall be oriented parallel to the piping. The distance between the nozzle outlets or distribution plate (if used) and the ceiling shall be 250 ± 100 mm for upright or pendent nozzles and mounted in false ceilings as described in Paragraph 8.11.1 for recessed and concealed nozzles.

8.20.2.4 Thermocouples

Two thermocouples, spaced 30 mm apart, shall be located 50 mm below the ceiling, at the center of the square formed by the nozzles. The tips of the thermocouples shall be turned upwards to avoid the formation of water droplets.

8.20.2.5 Procedure

Two tests at each installation height, each a duration of 30 minutes, shall be conducted.

For each test, a new wood crib, placed in the test stand in the center of the test room, shall be supplied with the heptane for 30 minutes, maintained at a temperature between 5°C and 25°C.

Continuous combustion of the heptane shall be assured by means of a pilot flame, igniter or other special device placed within 50 mm of the spray nozzle. The flow rate from each nozzle shall be the minimum flow rate specified for the first test and the maximum flow rate specified for the second test. The fuel flow is to be started, and the torch ignited immediately. When the torch is

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[6] A suitable nozzle is available commercially. Details may be obtained from the Secretariat of ISO/TC21 (BSI) or ISO Central Secretariat.

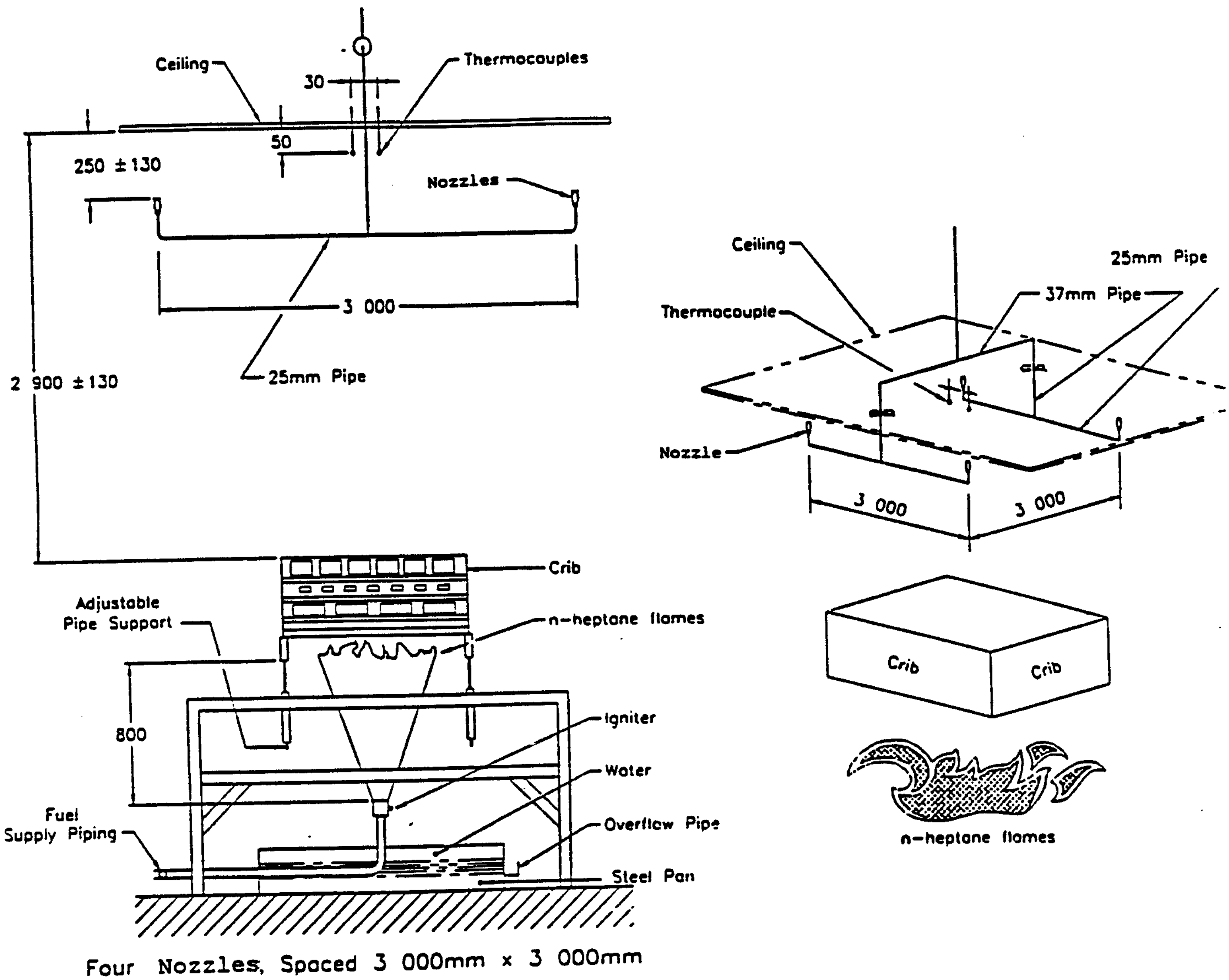

Figure 12. Fire Crib Set-Up Schematic (dimensions in millimeters)

ignited, the test timer and temperature-measuring equipment are to be started. Water application is to be started after a minimum free-burning time of 1 minute, or after a ceiling temperature of 760°C is achieved, whichever occurs last.

8.20.2.6 Performance Criteria

The test is considered to be successful if the following criteria is obtained:

A. The air temperature at the locations of the thermocouples shall be reduced to less than 275°C above the ambient temperature within the room at the start of the test, within 6 minutes of ignition,

B. The mean air temperature at the thermocouples shall not exceed 275°C above ambient temperature over the remaining 24 minutes of the test,

C. The air temperature at the thermocouples shall not exceed 275°C above ambient temperature for any continuous 3 minute period within the remaining 24 minutes of the test, and

D. The weight loss of the wood crib corrected to the value at zero percent moisture shall not exceed 20 percent.

8.21 Lateral Discharge Test (See 7.19)

Water is to be discharged from a spray nozzle at the maximum discharge pressure. A second automatic nozzle located at the minimum distance specified by the manufacturer is mounted on a pipe parallel to the pipe discharging water.

The nozzle orifices or distribution plates (if used), are to be placed 550 mm, 356 mm and 152 mm below a flat smooth ceiling for three separate tests, respectively. The top of a square pan measuring 305 mm square and 102 mm deep is to be positioned 152 mm below the heat responsive element for each test. The pan is filled with 0.47 liters of heptane. After ignition, the automatic nozzle is to operate before the heptane is consumed.

8.22 Thirty (30) Day Leakage Test (See 7.20)

Five nozzles are to be installed on a water filled test line maintained under a constant pressure of twice the rated pressure for 30 days at an ambient temperature of 20 to 25°C.

The nozzles shall be inspected visually at least weekly for leakage. Following completion of this 30 day test, all samples shall meet the leak resistance requirements specified in 7.2.4 and shall exhibit no evidence of distortion or other mechanical damage.

8.23 Vacuum Test (See 7.21)

Three nozzles shall be subjected to a vacuum of 460 mm of mercury applied to a nozzle inlet for 1 minute at an ambient temperature of 20 to 25°C. Following this test, each sample shall be examined to verify that no distortion or mechanical damage has occurred and then shall meet the leak resistance requirements specified in 8.4.1.

8.24 Water Shield Tests

8.24.1 Water Shield Angle of Protection Test (See 7.22)

8.24.1.1 Verify the angle of protection specified in 7.22. The angle of protection is that angle measured between the plane of the water shield and a line drawm from its lower outer edge to the lowest and outermost extremity of the heat responsive element.

8.24.1.2 For a nozzle having a link and lever type heat responsive element, this is the outermost and lowest edge of the link or lever measured with the link and lever assembly rotated to 90° to the frame arm plane.

8.24.1.3 For a center strut or glass bulb sprinkler: if a line drawn to the edge of the lower seat of the bulb, rather than to the extremity of the bulb, produces a larger angle, then that larger angle shall be the angle of protection.

8.24.2 Water Shield Rotation Test (See 7.23)

8.24.2.1 The water shield on each of three nozzles shall not rotate with an applied torque of up to 4.0 Nm. The toque shall be applied slowly and smoothly.

8.24.2.2 If the water shield rotates at less than 4.0 Nm, the shield shall be rotated 2 revolutions, and the nozzle then examined for a change in service load. If visual observation of the shield rotation indicates a change in service load, five samples shall have their shields rotated 2 revolutions and the average service load determined. The average service load shall not change more than ± 10%.

9.0 WATER MIST NOZZLE MARKING

9.1 General

Each nozzle complying with the requirements of this Standard shall be marked as follows:

a) trademark or manufacturer's name,
b) model identification,
c) manufacturer's factory identification; this is only required if the manufacturer has more than one nozzle manufacturing facility,
d) nominal year of manufacture[7] (automatic nozzles only),
e) nominal release temperature[8] (automatic nozzles only),
f) K-factor; this is only required if a given model nozzle is available with more than 1 orifice size.

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[7] The year of manufacture may include the last three months of the preceding year and the first six months of the following year.

[8] Except for coated and plated nozzles, the nominal release temperature range should be color-coded on the nozzle to identify the nominal rating. The color code should be visible on the yoke arms holding the distribution plate for fusible element nozzles, and should be indicated by the color of the liquid in glass bulbs. The nominal temperature rating should be stamped or cast on the fusible element of fusible element nozzles. All nozzles should be stamped, cast, engraved or color-coded in such a way that the nominal rating is recognizable even if the nozzle has operated. This should be in accordance with Table 3, page B-8.

In countries where color-coding of yoke arms of glass bulb nozzles is required, the color code for fusible element nozzles should be used.

9.2 Nozzle Housings

Recessed housings, if provided, shall be marked for use with the corresponding nozzles unless the housing is a non-removable part of the nozzle.

10.0 SYSTEM CONTROL (SHUT-OFF) VALVE REQUIREMENTS

10.1 Connections

All connections shall be suitable for use at the rated working pressure of the valve.

> **NOTE:** The dimensions of all connections should conform to International Standards, where these exist. National Standards may be used, if International Standards are not appropriate.

10.2 Bodies and Covers (See 10.11.7)

If non-metallic materials (other than gaskets and seals) or metals with a melting point of less than 800°C, form part of the valve body or cover, the assembled valve, after subjection to the fire exposure test of 10.11.7, shall withstand a hydrostatic pressure test without permanent deformation or failure and operate as intended.

10.3 Strength (See 10.11.1)

10.3.1 The assembled valve, with the sealing assembly open, shall withstand, without rupture, an internal hydrostatic pressure of four times the rated working pressure, for a period of 5 minutes when tested in accordance with 10.11.1.

10.3.2 The calculated design load of any pressure retaining fastener, neglecting the force required to compress the gasket, shall not exceed the minimum tensile strength specified in ISO 898-1 and 898-2, when the valve is pressurized to four times the rated working pressure. The area of the application of pressure shall be calculated as follows:

a) if a full-face gasket is used, the area of force application is that extending out to a line defined by the inner edge of the bolts, and

b) if an 'O'-ring seal or ring gasket is used, the area of force application is that extending out to the centerline of the 'O'-ring or gasket.

10.4 Components

10.4.1 Where practicable, the design of any component which may normally be disassembled during servicing shall be such that it cannot be reassembled wrongly, without providing an external visual indication, when the valve is returned to service. With the exception of the valve seat, all parts intended for field replacement shall be capable of being disassembled and reassembled with tools normally employed by the trade.

10.4.2 Internal components exposed to the water supply shall be constructed of corrosion resistant materials.

10.4.3 The shaft of a valve shall be constructed of austenitic stainless steel, bronze, brass or equivalent material.

10.4.4 The shaft of a valve shall be capable of transmitting the maximum operating torque without exceeding a torsional shear stress of:

1) 40 percent of the yield strength, and
2) 18 percent of the ultimate tensile strength of the shaft material (see 10.11.4).

10.5 Indicating Means

A valve shall be provided with an indicating arrangement that will positively indicate when the valve is in the open and closed position. The indicator shall be visible from two positions 180 degrees apart, at a distance of 15 m. The valve indicating means shall include the words "open" and "closed" to provide the user with information to the position of the valve.

10.6 Leakage (See 10.11.2)

Sealing surfaces and valve body assembly shall prevent leakage of water, when subjected to a hydrostatic pressure of twice the rated working pressure for five minutes, when tested by the methods of 10.11.2.

10.7 Hydraulic Pressure Loss (See 10.11.3)

A valve shall be tested by the methods of 10.11.3 to determine the loss characteristics through the valve.

10.8 Operation (See 10.11.4)

A valve shall:

1) not be capable of being operated from the full open position to the closed position in less than 5 seconds, and
2) fully open and close without exceeding a force of 125 N applied to the gripping portion of the handwheel, handcrank a handle when tested by the methods of 10.11.4.

10.9 Mechanical Strength (See 10.11.5)

A valve shall withstand the effects of a 310 N closing or opening force without damage, when tested by the methods of 10.11.5.

10.10 Cycling (See 10.11.6)

A valve shall withstand, without damage, 1000 cycles of operation from the full open to the full closed position when tested by the methods of 10.11.6.

10.11 Methods of Test

10.11.1 Strength of Body Test (See 10.2)

The test sample is to be filled with water and all air expelled. With the valve partially opened, the pressure is to be increased at a uniform rate until four times the rated working pressure of the valve is achieved. This test pressure is to be held for 5 minutes while observations are made for rupture.

10.11.2 Leakage Test (See 10.6)

10.11.2.1 The inlet of the test sample is to be connected to a water supply and all air expelled. With the valve in the closed position, the pressure is to be increased to twice the rated working pressure for a period of five minutes while observations are made for leakage past the valve seat.

10.11.2.2 After completion of the test in 10.11.2.1, the outlet of the sample is to be closed by a cap or the equivalent, and the sample partially opened to allow pressurization of the entire body. The sample is then to be pressurized to twice the rated working pressure and maintained at that pressure for 5 minutes.

10.11.3 Hydraulic Pressure Loss Test (See 10.7)

10.11.3.1 Install the test valve in a test arrangement using piping of the same nominal diameter. Use a differential pressure measuring device accurate to ± 2%.

10.11.3.2 Measure and record the differential pressure across the valve at a range of flows above and below the value corresponding to a flow of 4.8 m/s. Replace the valve in the test rig by a section of pipe, of the same nominal size, and measure differential pressure over the same range of flows. Using graphical methods, determine the pressure drops at the flowing velocity of 4.8 m/s. Record the hydraulic pressure loss as the difference between the pressure drop across the test valve and the pressure drop across the replacement pipe.

10.11.4 Operation Test (See 10.8)

10.11.4.1 With no water flowing through the valve, the valve is to be operated as quickly as possible from the full open position to the full closed position. The time required to move the valve from the full open position to the full closed position shall be measured with a stop watch.

10.11.4.2 The test samples are to be connected to a piezometer to which a pressure gauge has been attached, and to a water supply capable of providing:

1) the valve's maximum rated working pressure when the valve is 90 percent closed, and
2) a flowing velocity of 5 m/s.

10.11.4.3 The flow at 5 m/s is to be based upon the open area in Schedule 40 pipe of the same nominal size as the valve.

10.11.4.4 The valve is to be closed and the inlet pressure of the piezometer is to be increased to the maximum rated working pressure. The valve then is to be opened to the "open" position until a flowing velocity of 5 m/s is to be established. The valve then is to be closed. The inlet pressure is to be maintained at the maximum rated working pressure while the valve is 90 percent closed.

10.11.4 5 Test measurements are to be made of the operating torque required to close the valve to the point that flow is stopped, to fully close it, to open it to the point where leakage begins, and to fully open it.

10.11.5 Mechanical Strength Test (See 10.9)

The sample valve is to be installed in a test fixture in a manner in which the valve handwheel, handle or handcrank can be subjected to a force. A force of 310 N is to be applied to the outside diameter of the handwheel or extreme end of the handle or handcrank intended for use with the valve. The test is to be conducted against the opening stop and closing stop. After the test, the valve shall comply with the requirements of 10.6 and 10.8.

10.11.6 Cycling Test (See 10.10)

The test valve shall be connected to a hydrostatic pressure source capable of supplying the rated working pressure of the valve. The valve is to be cycled 1000 times from the full open to the full closed position with a hydrostatic pressure differential applied across the closed seat equal to the rated working pressure. After the cycling, the valve shall comply with the requirement of 10.6.

10.11.7 Fire Exposure Test (See 10.2)

10.11.7.1 The valve is to be mounted horizontally with body openings sealed and fill the test sample with water. The valve is then vented of air.

10.11.7.2 A fire tray, having a surface area not less than 1 m^2, is positioned centrally beneath the sample valve. Sufficient volume of a suitable fuel is placed in the tray to give an average air temperature between 800 and 900°C around the sample valve for a period of 15 minutes after a temperature of 800°C is reached.

10.11.7.3 The temperature is measured with thermocouples positioned 10 mm from the surface of the sample valve on a horizontal plane parallel to the axis at the mid-point between the mounting flanges.

> **CAUTION** - Insure that the test valve is open to atmosphere while testing to permit venting of any pressure buildup.

10.11.7.4 The fuel is ignited and 15 minutes after 800°C is attained, remove the fire tray or extinguish the fire. Starting within 1 minute of extinguishment, or removal of the tray, the sample valve is cooled by flushing with 100 liters of water for 1 minute.

10.11.7.5 The sealing assembly shall be capable of opening as intended. The sample valve is to be subjected to an internal hydrostatic pressure by the method of 10.11.1 using the requirements of 10.3.1.

10.12 Marking Requirements

System control valves shall be permanently marked with the following:

a) name or trade mark of the manufacturer or vendor,
b) distinctive model number, catalogue designation or equivalent marking,
c) indication of flow direction, if flow is intended in a single direction only,
d) nominal size,
e) maximum working pressure in bar (or MPa)
f) serial number or year of manufacture; valves produced in the last three months of a calendar year may be marked with the following year as the date of manufacture: valves produced in the first six months of a calendar year may be marked with the previous year as the date of manufacture, and
g) factory or origin, if manufactured at two or more factories.

11.0 TEST, TRIM AND DRAIN VALVE REQUIREMENTS

11.1 Connections

All connections shall be suitable for use at the rated working pressure of the valve.

> **NOTE:** The dimensions of all connections should conform to International Standards, where these exist. National Standards may be used if International Standards are not appropriate.

11.2 Bodies and Covers (See 11.7.4)

If non-metallic materials (other than gaskets and seals) or metals with a melting point of less than 800°C, form a part of the valve body or cover, the assembled valve, after subjection to the fire exposure test of 11.7.4, shall withstand a hydrostatic pressure test without permanent deformation or failure, and operate as intended.

11.3 Strength (See 11.7.1)

The assembled valve with the sealing assembly open shall withstand, without rupture, an internal hydrostatic pressure of four times the rated working pressure, for a period of 5 minutes when tested in accordance with 11.7.1.

11.4 Components

11.4.1 Where practicable, the design of any component which may normally be disassembled during servicing shall be such that it cannot be reassembled wrongly, without providing an external visual indication, when the valve is returned to service. With the exception of the valve seat, all parts intended for field replacement shall be capable of being disassembled and reassembled with tools normally employed by the trade.

11.4.2 Internal components exposed to the water supply shall be constructed of corrosion resistant materials.

11.4.3 The shaft of a valve shall be constructed of austenitic stainless steel, bronze, brass or equivalent material.

11.4.4 The shaft of a valve shall be capable of transmitting the maximum operating torque without exceeding a torsional shear stress of:

1) 40 percent of the yield strength, and
2) 18 percent of the ultimate tensile strength of the shaft material. See 11.7.3.2.

11.5 Leakage (See 11.7.2)

Sealing surfaces and valve body assembly shall prevent leakage of water when subjected to a hydrostatic pressure of twice the rated working pressure for five minutes when tested by the methods of 11.7.2.

11.6 Mechanical Strength (See 11.7.1)

A test, trim or drain valve shall exhibit no malfunction of the stem assembly, handle or other operating parts when subjected to three times the normal operating torque of the valve when tested by the methods of 11.7.3.

11.7 Methods of Test

11.7.1 Strength of Body Test (See 11.6)

The test sample is to be filled with water and all air expelled. With the valve partially opened, the pressure is to be increased at a uniform rate until four times the rated working pressure of the valve is achieved. This test pressure is to be held for 5 minutes while observations are made for rupture.

11.7.2 Leakage Test (See 11.5)

11.7.2.1 The inlet of the test sample is to be connected to a water supply and all air expelled. With the valve in the closed position, the pressure is to be increased to twice the rated working pressure for a period of five minutes while observations are made for leakage past the valve seat.

11.7.2.2 After completion of the test in 11.7.2.1, the outlet of the sample is to be closed by a cap or the equivalent, and the sample partially opened to allow pressurization of the entire body. The sample is then to be pressurized to twice the rated working pressure and maintained at that pressure for 5 minutes.

11.7.3 Mechanical Strength Test (See 11.3)

11.7.3.1 The test valves are to be held in a vise or by other equivalent means. The force is to be applied at 12.5 mm from end of handle and measured using a calibrated torque wrench or a spring scale secured to the handle at a measured distance from the center of rotation. If the valve is fitted with a handwheel, the force shall be applied to the perimeter of the handwheel. The torque applied to the stem shall be calculated by multiplying the distance from the center line of the valve stem to the point of application of the force by the value of the applied force.

11.7.3.2 The torque required to operate the valve under rated pressure is to be measured and recorded. A torque value equivalent to three times the torque recorded shall be calculated. The stem assembly, consisting of the stem, stem nut, valve seat seal and the handle attached to the stem with the valve body obstructed, shall be subjected to the above determined mechanical strength test value.

11.7.3.3 Separately, a sample valve shall be subjected to a mechanical strength test using a torque value specified in Table 11.

Table 11. Minimum Torque Values

Handle Length or Handwheel Diameter (mm)	Torque N • m
63 or less	16
66	20
72	34
82	43
90	55
101	81
111	95
127	122
154	170

11.7.3.4 Mechanical strength test method shall be applied in a manner similar to the method in 11.7.3.2 except that a 5 mm diameter steel rod is to be inserted through the valve body and opening in the ball in order to prevent the valve from closing.

11.7.3.5 Minimum torques for a valve having other handwheel diameters are to be interpolated or extrapolated from the values in Table 11.

11.7.4 Fire Exposure Test (See 11.2)

11.7.4.1 The sample valve is to be mounted horizontally with body openings sealed and the sample valve filled with water. The valve is to be vented of air.

11.7.4.2 A fire tray, having a surface area not less than 1 m^2 is positioned centrally beneath the sample valve. A sufficient volume of a suitable fuel is to be placed in the tray to give an average air temperature between 800 and 900°C around the sample valve for a period of 15 minutes after a temperature of 800°C is reached.

11.7.4.3 The temperature with thermocouples positioned 10 mm from the surface of the sample valve on a horizontal plane parallel to the axis at the mid-point between the mounting flanges is to be measured.

> **CAUTION** - Insure that the test valve is open to atmosphere while testing to permit venting of any pressure buildup.

11.7.4.4 The fuel is ignited and 15 minutes after 800°C is attained, the fire tray is removed or the fire extinguished. After 1 minute of extinguishment, or removal of the tray, the sample valve is to be cooled by flushing with 100 liters of water for 1 minute.

11.7.4.5 The sealing assembly shall operate as intended. Test the sample valve to an internal hydrostatic pressure by the method of 11.7.1 and verify that it meets the requirements of 11.3.

11.8 Marking Requirements

Each valve shall be permanently marked with the following:

a) name or trademark of the manufacturer or vendor,
b) nominal size of valve,
c) distinctive model designation, catalogue designation, or equivalent marking,
d) rated working pressure,
e) an arrow on the valve handle, clearly legible, showing the direction to turn the handle for the "open" and "closed" positions,
f) serial number or year of manufacture; values produced in the last three months of a calendar year may be marked with the following year as the date of manufacture; valves produced in the first six months of a calendar year may be marked with the previous year as a date of manufacture, and
g) factory of origin, if manufactured at two or more factories.

12.0 PRESSURE REGULATING VALVE REQUIREMENTS

Valves used to regulate the water flowing pressure shall comply with the application requirements of the Standard for Pilot Operated Pressure Control Valves, ANSI/UL 1739. Valves used to regulate air or nitrogen pressure shall comply with the applicable requirements of the Standard for Compressor Gas Regulators, ANSI/UL 252.

13.0 CHECK VALVE REQUIREMENTS

Check valves shall comply with the applicable requirements of the International Standards, ISO 6182-6, Fire Protection-Automatic Sprinkler Systems Part 6: Requirements and Methods of Test for Check Valves.

14.0 PIPELINE STRAINER REQUIREMENTS

14.1 Connections

All connections shall be suitable for use at the rated working pressure of the strainer.

> **NOTE:** The dimensions of all connections should conform to International Standards, where these exist. National Standards may be used if International Standards are not appropriate.

14.2 Bodies and Covers (See 14.8.4)

14.2.1 If non-metallic materials (other than gaskets and seals) or metals with a melting point of less than 800°C, form part of the strainer body or cover, the assembled valve, after subjection to the fire exposure test of 14.8.4, shall withstand a hydrostatic pressure test without permanent deformation or failure.

14.2.2 The body and cover shall be made of a corrosion resistance material.

14.3 Strength (See 14.8.1)

14.3.1 The assembled strainer shall withstand, without rupture, an internal hydrostatic pressure of four times the rated working pressure, for a period of 5 minutes when tested in accordance with 14.8.1.

14.3.2 The calculated design load of any pressure retaining fastener, neglecting the force required to compress the gasket, shall not exceed the minimum tensile strength specified in ISO 898-1 and 898-2, when the strainer is pressurized to four times the rated working pressure. The area of the application of pressure shall be calculated as follows:

a) if a full-face gasket is used, the area of force application is that extending out to a line defined by the inner edge of the bolts, and

b) if an 'O'-ring seal or ring gasket is used, the area of force application is that extending out to the centerline of the 'O'-ring or gasket.

14.4 Components

14.4.1 Where practicable, the design of any component which may normally be disassembled during servicing shall be such that it cannot be reassembled wrongly, without providing an external visual indication, when the strainer is returned to service.

14.4.2 Internal components exposed to the water supply shall be constructed of corrosion resistant materials.

14.5 Construction

14.5.1 The maximum dimension of a hole in the strainer shall not exceed two thirds of the diameter of the smallest orifice to be protected by the strainer.

14.5.2 The total area of openings in the strainer shall be at least 20 times the area of the openings to be protected by the strainer or 4 times the area of the inlet pipe, whichever is greater.

14.6 Body Leakage (See 14.8.2)

A strainer body shall prevent leakage of water when subjected to a hydrostatic pressure of twice the rated working pressure for 5 minutes when tested by the methods of 14.8.2.

14.7 Hydraulic Pressure Loss (See 14.8.3)

A strainer shall be tested in accordance with 14.8.3 to determine the pressure loss characteristics to be referenced in the Design, Installation, Operation and Maintenance Manual (See 22).

14.8 Methods of Test

14.8.1 Strength of Body Test (See 14.3)

The test sample is to be filled with water and all air expelled. The pressure is to be increased at a uniform rate until four times the rated working pressure of the strainer is achieved. This test pressure is to be held for 5 minutes while observations are made for rupture.

14.8.2 Leakage Test (See 14.6)

14.8.2.1 The inlet of the test sample is to be connected to a water supply and all air expelled. With the valve in the closed position, the pressure is to be increased to twice the rated working pressure for a period of 5 minutes, while observations are made for leakage past the valve seat.

14.8.2.2 After completion of the test in 14.8.2.1, the outlet of the sample is to be closed by a cap or the equivalent, and the sample partially opened to allow pressurization of the entire body. The sample is then to be pressurized to twice the rated working pressure, and maintained at that pressure for 5 minutes.

14.8.3 Hydraulic Pressure Loss (See 14.7)

14.8.3.1 The strainer is to be installed in a test arrangement using piping of the same nominal diameter. A differential pressure measuring device accurate to ± 2% is to be used.

14.8.3.2 The differential pressure across the valve, at a range of flows above and below the value corresponding to a flow of 4.8 m/s, is to be measured and recorded. The strainer is to be replaced in the test rig by a section of pipe, of the same nominal size, and the differential pressure over the same range of flows is then measured. Using graphical methods, the pressure drops at the flowing velocity of 4.8 m/s is determined. The hydraulic pressure loss, as the difference between the pressure drop across the strainer and the pressure drop across the replacement pipe, is to be recorded.

14.8.4 Fire Exposure Test (See 14.3)

14.8.4.1 The strainer is to be installed horizontally with body openings sealed and fill the strainer with water. The strainer shall be vented of air from the assembly.

14.8.4.2 A fire tray, having a surface area not less than 1 m^2 is positioned centrally beneath the strainer. A sufficient volume of a suitable fuel in the tray is placed to give an average air temperature between 800 and 900°C around the strainer for a period of 15 minutes after a temperature of 800°C is reached.

14.8.4.3 The temperature with thermocouples positioned 10 mm from the surface of the strainer on a horizontal plane parallel to the axis of the mid-point between the mounting flanges shall be measured.

> **CAUTION** - Insure that the test valve is open to atmosphere while testing to permit venting of any pressure buildup.

14.8.4.4 The fuel is to be ignited and 15 minutes after 800°C is attained, the fire tray is to be removed or the fire extinguished. After 1 minute of extinguishment, or removal of the tray, the strainer is cooled by flushing it with 100 liters of water over 1 minute.

14.8.4.5 Test the strainer to an internal hydrostatic pressure by the method of 14.81. and verify that it meets the requirements of 14.3.1.

14.9 Marking Requirements

Pipeline strainers shall be permanently marked with the following:

a) name or trade mark of the manufacturer or vendor,
b) distinctive model number, catalogue designation or equivalent marking,
c) indication of flow direction,
d) nominal size,
e) maximum working pressure in bar (or MPa),
f) serial number or year of manufacture; strainers produced in the last three months of a calendar year may be marked with the following year as the data of manufacture; strainers produced in the first six months of a calendar year may be marked with the previous year as the date of manufacture, and
g) factory or origin, if manufactured at two or more factories.

15.0 WATER PUMP REQUIREMENTS

Pumps used to increase the water pressure in a high pressure water-fog suppression system, shall comply with the applicable requirements of the Standard for Pumps for Fire Protection Service, ANSI/UL 448.

16.0 ELECTRIC PUMP DRIVER REQUIREMENTS

Electric motors used to drive water pumps shall comply with the NEMA Standard MG-1 and be marked as complying with NEMA Design B Standards or other equivalent international requirements.

17.0 PUMP CONTROLLER REQUIREMENTS

Pump controllers shall comply with the applicable requirements of the Standard for Electric Industrial Control Equipment, UL 508 or other equivalent international requirements.

18.0 PRESSURE GAUGE REQUIREMENTS

Pressure gauges shall comply with applicable requirements of the Standard for Indicating Pressure Gauges, ANSI/UL 393.

19.0 PRESSURE VESSEL REQUIREMENTS

Pressure vessels shall comply with the applicable requirements of the United States Department of Transportation or other equivalent national requirements.

20.0 ELECTRICAL ALARM

Alarm devices and electrical controller units shall comply with the applicable requirements of the Standard for Control Units for Fire Protection Signaling Systems, ANSI/UL 864.

21.0 PRESSURE OPERATED SWITCHES

Pressure operated switches shall comply with the applicable requirements in the Standard for Alarm Accessories for Automatic Water-Supply control Valves for Fire Protection Service, ANSI/UL 753.

22.0 DESIGN, INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

22.1 General

A copy of the installation, operating, refilling, inspection, and maintenance instruction manual is to be furnished for use as a guide in the examination and testing of any high pressure water fog suppression system devices.

22.2 Requirements

The instructions shall reference the limitations of each device and shall include at least the following items:

a) description and operating details of each device and all accessory equipment, including identification of extinguishing system components or accessory equipment by part or model number,

b) degree and type of protection afforded by the system and associated design density limitation for each fire use type,

c) a description of the method to be used for sizing pumps, motors, controllers, and required power to drive the pumps,

d) type of pipe, tubing, and fittings to be used,

e) equivalent length values of all fittings and all system equipment through which water flows,

f) typical system layout and specific limitations and recommendations for correct system installation and effective protection,

g) description of all installation variations of an installed systems, including the limitations for each variation,

h) discharge nozzle limitations, including maximum dimensional and area coverage, minimum and maximum installation height limitations, and nozzle location in the protected volume,

i) range of filling capacities for each size storage container,

j) operating temperature range limitations for each temperature nozzle,

k) details for the proper installation of each device, including all component equipment,

l) reference to the specific types of detection and control panels (if applicable) to be connected to the equipment,

m) specifications and instructions for interconnection of multiple systems, or a caution statement to not use multiples of units, if a means for interconnecting is unavailable,

n) operating pressure ranges of the system,

o) information on inspection of system after installation,

p) detailed instructions for restoring the system after operation that shall:
   1) contain
      a) necessary warnings, and cautions,
      b) a description of servicing equipment, and
      c) a description of recommended procedures for intended servicing, and
   2) provide a list of part numbers of all replacement parts.

q) description of requirements for maintenance of all equipment,

r) reference to the applicable portions of the Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, NFPA 25,

s) the name of the manufacturer or private labeler, or equivalent designation, and

t) date and manual designation number on each page.

ENCLOSURE TO APPENDIX B

Notes on the Strength Test for Nozzle Release Elements

The formula, given in Paragraph 7.2.9.2, is based on the intention of providing fusible elements that are not susceptible to failure caused by creep stresses during a reasonable period of service. As such, the duration of 876,600 hours (100 years) was selected only as a statistical value with an ample safety factor. No other significance is intended, as many other factors govern the useful life of a nozzle.

Loads causing failure by creep, and not by an unnecessarily high initial distortion stress, are applied and the times noted. The given requirement then approximates to the extrapolation of the full logarithmic regression curve by means of the following analysis.

The observed data is used to determine, by means of the method of least square, the load at 1 hour, L_0, and the load at 1000 hours, L_M. One way of stating this is that, when plotted on full logarithmic paper, the slope of the line determined by L_M and L_0 shall be greater than or equal to the slope determined by the maximum design load at 100 years, L_d, and L_o or

$$(\ln L_m - \ln L_o)/\ln 1000 \geq (\ln L_d - \ln L_o)/\ln 876{,}600$$

This is then reduced as follows:

$$ln\, L_m \geq (\ln L_d - \ln L_o) \frac{\ln 1000}{\ln 876{,}600} + \ln L_o$$

$$\geq 0.5048\ (\ln L_d - \ln L_o) + \ln L_o$$

$$\geq 0.5048 \ln L_d + \ln L_o\ (1 - 0.5048)$$

$$\geq 0.5048 \ln L_d + 0.4952 \ln L_o$$

With an error of approximately 1%, the formula may be approximated by:

$$\ln L_m \geq 0.5\ (\ln L_d + \ln L_o)$$

or, compensating for errors

$$L_m \geq 0.99\ (L_d - L_o)^{0.5}$$

or

$$L_d \leq 1.02\ L_m^2 / L_o$$